THE GROUND ENGINEER'S MANUAL

BY

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LONDON

GEORGE NEWNES, LIMITED

TOWER HOUSE, SOUTHAMPTON STREET,

STRAND, W.C.2

First Published March, 1939 5,000 copies
Reprinted September, 1939 5,000 „
Reprinted February, 1940 5,000 „
Reprinted July, 1940 5,000 „
Reprinted December, 1940 5,000 „
Reprinted March, 1941 20,000 „
Reprinted August, 1941 20,000 „

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PREFACE

THE object of this book is to assist the student and practical man in the study of aircraft engineering. I have frequently heard points raised in the course of discussions regarding a subject, for instance, " Why will duralumin age-harden," and again " How is the annual ring formed in timber," or " What defects would you look for in a welded fitting," which brought to mind the need for a book giving explanations to such queries. These notes may seem very brief, but good technical books dealing fully with these subjects can always be obtained. The testing of aircraft materials is carried out as laid down by the British Standards Institution, who will supply full information on this subject. I am indebted to Mr. L. White and others for many helpful suggestions and criticisms. I trust this book will answer the purpose for which it was published.

A. C. ROBINSON
(Lecturer in Aircraft Construction.)

TIMBER

1. Name a Few Trees Belonging to the Coniferous Group.

Firs, spruces and pines.

2. What is Meant by "Coniferous"?

This term denotes the type of foliage and seed-bearing peculiarities, the leaves being of needle-like shape and the seeds cone-borne. These types of tree yield the soft woods.

3. What type of Leaves have Non-Coniferous Trees?

Broad and flat; the hard woods, ash, oak and teak belong to this group.

4. What is Meant by a Tree Belonging to the Exogenous Group?

This term refers to trees which grow diametrically by the development outwards of additional layers or rings. These trees yield material suitable for constructional purposes.

5. What Part of a Tree is the Medulla?

The pith, which consists of a mass of soft-walled tissue.

6. Of what is the Cortex Composed?

The cortex is the bark and is composed of a thick-walled layer of fibres known as inner bark or bast, next a layer of juice-carrying cells, and the final outer layer of cork-type wood.

7. How is the Annual Ring Formed?

In the spring the roots absorb moisture from the earth. The moisture consists of mineral salts in solution, and it ascends, passing by way of the stem and branches, to the leaf buds, which expand under its influence and the leaves develop, after which the leaves convert the sap into wood-forming matter. During summer and autumn the sap undergoes chemical changes and descends to the roots. This perfected sap descending forms a ring which later practically solidifies.

8. Explain the Terms "Duramen" and "Alburnum."

The inner zone of a tree is the Duramen or heartwood, and the outer zone consists of sapwood called the Alburnum. The sapwood is softer and lighter in colour than the heartwood, and also of less density.

9. At What Time of the Year should Trees be Felled?

In temperate climates—winter, i.e. when the sap is at rest. In tropical climates—in the dry season.

10. What are the Medullary Rays?

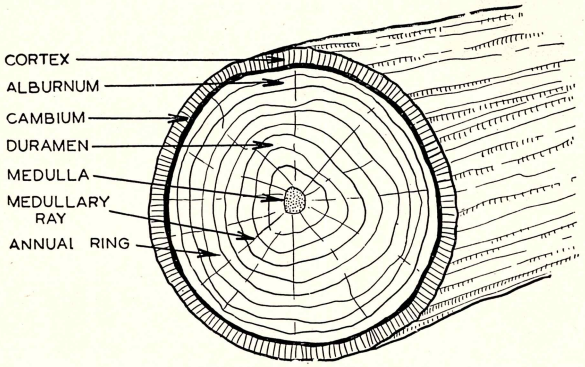
Veins radiating from the centre of a tree and acting as ducts conveying sap to the heartwood.

11. In What Part of a Tree will Diametral Growth take Place?

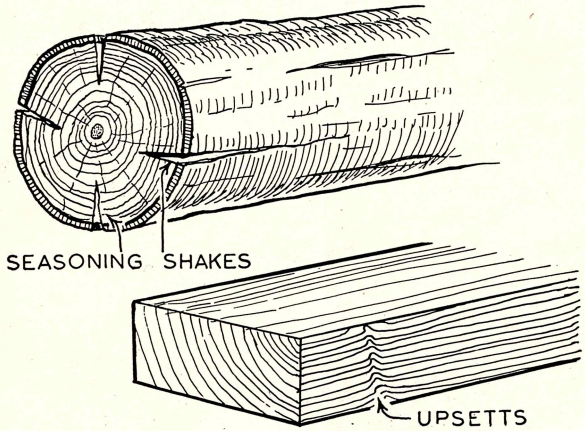
There is a thin tissue between the Cortex and Alburnum named Cambium. Cambium is the source of diametral growth.

12. Why is the Moisture Content of Timber very Important?

If the moisture content is high, then the timber will be unstable, i.e. with a tendency to warp or shrink. If the moisture content is low, then the timber will be brittle and weak.



CROSS-SECTION OF LOG, SHOWING HOW DETAILS OF STRUCTURE ARE NAMED



TWO COMMON DEFECTS FOUND IN TIMBER

13. What are the Defects or Diseases to be Looked for in Timber?

Spiral grain, cross grain, shakes, knots, dote, wet or dry rot, etc.

14. What is Spiral Grain?

This defect is an inclination of the fibre of the annual ings, caused by the tree being exposed to high winds, the trunk of the tree being twisted.

15. What is Cross Grain?

This is caused by a knot, the grain being diverted from the straight, or by the result of incorrect conversion.

16. What are Heart Shakes?

These are defects that occur in the growing tree, and are radiating clefts in the centre of the tree.

17. What are Cup Shakes?

These are shakes which follow the path of the annual ring. These shakes often interfere seriously with the amount of material obtained from the tree during conversion. The cause is attributed to high winds swaying the tree, or to the action of excessive frosts on the moisture in the tree.

18. What are Fiddle Back Shakes or Upsetts?

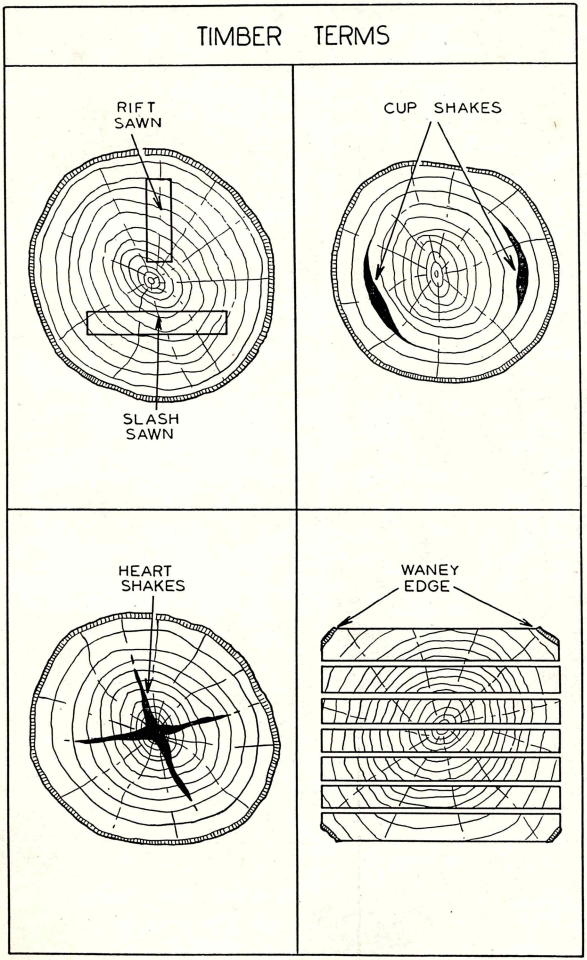
These are shakes across the grain and caused through careless handling in the felling and transport of the tree.

19. What are Seasoning Shakes?

These occur when the timber shrinks through exposure during seasoning. This causes the outer rings of tissue to dry faster than the inner ones. The resulting shrinkage sets up numerous radial clefts in the log.

20. What are Knots?

Knots are the bases of branches, dead and live knots being the remains of dead or broken branches.


TIMBER TERMS
RIFT SAWN
SLASH SAWN
CUP SHAKES
HEART SHAKES
WANEY EDGE

21. What is Dote?

Dote is a form of incipient decay, indicated by a dull white or greyish stain, sometimes speckled with black.

22. What is Dry Rot?

This disease is caused by a fungus growth which reduces the fibres of the wood to a powder. It attacks unseasoned timber where there is not a free access of air.

23. What is Wet Rot?

This is the decomposition of the fibres of the wood, and may take place while the tree is growing. It is induced by the wood becoming saturated with water.

24. What is Foxiness?

This appears as reddish-brown stains which indicate commencement of decay, probably set up by overmaturity.

25. What is Druxiness?

Decomposition, due to a collection of water in a cavity, as may be formed by the breaking off of a branch. It shows on timber as spots or streaks, light in colour.

26. What are Rind Galls?

These are curved swellings produced by the formation of new layers over an injured part, caused by a branch having been broken off.

27. What is Caney Grain?

It is just what its name implies and is clearly indicated on the end of the wood, which appears very porous. Ash with this defect is useless for aircraft construction.

28. What is Rammy Grain?

The grain, instead of being straight, is curled.

29. What is Waney Edge?

Due to the shape of certain logs it is impossible, without considerable waste, to square the log perfectly, with the result that certain planks cut from the balk will have the bark on their edges. This edge is termed WANEY EDGE.

30. What is Meant by "Springwood" and "Autumnwood"?

Springwood is that portion of the annual layer which is formed by the ascending sap during spring. Autumnwood is that portion of the annual layer which is formed by the descending sap during the summer and autumn. Autumnwood is greater in density than springwood.

31. What is the Object of Seasoning Timber?

To improve its strength and mechanical properties.

To decrease shrinkage, and therefore reduce the possibility of warping.

To increase its resistance to decay.

32. Explain the Term "Seasoning" (Natural).

Green timber—i.e. timber freshly felled—has a high moisture content and contains natural juices. The timber is submitted to the action of the weather, in sheds with open sides, from 3 to 18 months, the time depending upon the type of timber. During this period the natural juices harden and the moisture content is reduced by evaporation.

33. What are Other Methods of Seasoning Timber?

Wet seasoning or hot air seasoning (kiln method).

34. Explain Wet Seasoning.

The logs are anchored under running water from 2 to 6 weeks, care being taken to ensure that the logs are completely submerged. By this method a large quantity of the sap is removed. On completion of this process the logs are dried by being stacked in the open air.

35. Explain Hot Air Seasoning.

The timber is stacked in the kiln from 10 to 30 days, the temperature and humidity being controlled. The temperature must not exceed 221° F.

36. What is the best Method of Seasoning Timber?

The natural method. Other methods generally diminish the strength of timber.

37. What Advantage has Rift-Sawn Timber over Slash-Sawn?

Rift-sawn timber is cut with the direction of the annual rings, parallel with the thickness, and slash-sawn with the direction of the annual rings parallel with the width. Rift-sawn timber is less liable to shrinkage or warping.

38. Name some Varieties of Timber Used in Aircraft Construction.

Spruce, ash, mahogany, walnut, balsa.

39. Describe Spruce.

Spruce, known as Sitka Spruce, grown in British Columbia, colour bright brownish yellow, specified density 24 lb. per cu. ft., must be seasoned to a moisture content of 15% to 17%, rate of growth must not be less than 18 annual rings to any 3 in., grain or fibre must not deviate by more than 1 in 15. This timber is used for struts, spars, ribs, longerons, also hull and float construction.

40. Describe Ash.

Ash is British grown, colour whitish yellow to yellow brown, specified density 38 lb. per cu. ft. Its moisture content must not exceed 16%, and the rate of growth of strong timber is about 4 annual rings to the inch. The inclination of the grain must not exceed 1 in 10. This timber is used for fuselage, tail skids, engine bearers, and also as outer veneers of plywood.

41. Describe Mahogany.

Honduras mahogany is obtained from Central America, colour reddish brown to dull red, specified density 32 lb. per cu. ft. Its moisture content must not exceed 14%, and the inclination of grain must not exceed 1 in 12. This timber is used for airscrews, etc.

42. Describe Walnut.

American Black Walnut, which is generally used, is dark brown in colour, specified density 35 lb. per cu. ft. Its moisture content must not exceed 13%, and the inclination of grain must not exceed 1 in 12. This timber is used for airscrews and packing blocks, etc.

43. Describe Balsa.

Grown in South America, this is the lightest of woods, and is used for fairings on struts, its weight per cu. ft. being about 10 lb.

44. Why is Spruce Generally used in Aircraft Construction?

Spruce is used for lightness, straight grain and strength.

45. Why are Airscrews Generally made with Mahogany?

Mahogany is strong, hard, straight-grained wood, and when seasoned is not likely to shrink or warp under ordinary conditions. It also has good glue-retaining qualities.

46. What Characteristics has Ash?

Ash is very strong, tough and elastic.

47. How is Timber Examined for Spiral Grain?

This defect will be found by examining the flower side or figured surface of the timber. If convenient a short piece of the timber should be removed and split at right-angles to the annual rings, the grain slope being indicated by the direction of the sides of the split. If the timber cannot be examined by this method and

the run of the fibre grain is doubtful, a spot of ink applied to the flower side will run in the true direction of the grain.

48. How is Spruce Tested for Moisture Content ?

A small sample of the timber is removed from the plank, cut into small sticks and immediately weighed. The sticks are then dried in an oven at 100° C. until two successive weighings are identical. The percentage of moisture is then calculated by this formula :

$$\frac{W^1 - W^2}{W^2} \times 100$$

W^1 = Weight of sticks before drying.
W^2 = Weight of sticks after drying.

$$\therefore \frac{24 - 20}{20} \times 100$$

$$= 20\%$$

49. If the Moisture Content was 10% and the Timber Weighed 30 lb., What would be the Weight of the Moisture in the Timber ?

2·7 lb. approx.

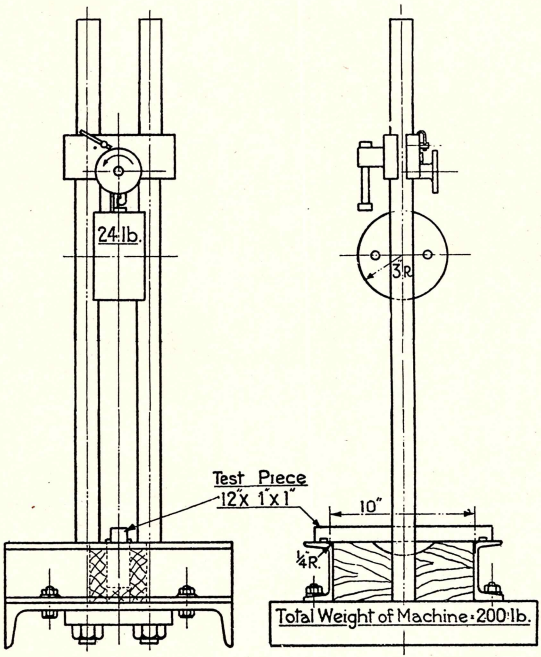
50. How is the Timber Tested for Brittleness ?

By the impact test or Drop Impact test.

51. Explain the Drop Impact Testing Machine.

This machine consists of a free-to-fall 24 lb. weight, the striking surface of which has a radius of 3 in. In accordance with requirements, the height of the fall of the weight may be varied. The test piece is placed on supports 10 in. apart, situated at the base of the machine. The weight is clamped in position above the test piece at the specified height, released, and falling between the guides strikes the test piece, which should then show no sign of fracture.

DROP IMPACT TESTING MACHINE



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52. How is the Test Piece Prepared?

It should measure 12 × 1 × 1 in., cut parallel to the grain. It is positioned centrally on the supports so that the blow is applied in a tangential direction to the annual rings.

53. From What Height is the Weight Dropped for Spruce?

6·5 in. (13 ft. lb.), though a further blow at half the previous energy, i.e. 3·25 in. (6·5 ft. lb.), may be applied if there is any doubt, and again the test piece must show no sign of fracture. It must be mentioned that a few fibres opening out must not be taken as indicative of failure.

54. Explain the Impact Test.

The machine used consists of a pendulum which carries a 10 lb. tup, swinging in a vertical plane. A vice is fixed to the bed of the machine in which the test piece is held. That part of the test piece coming in contact with the tup is protected with a steel plate. The pendulum is clamped in position and when released swings down through a 2 ft. radius, the tup breaking the test piece. Owing to the momentum of the tup it continues its swing, but, as energy has been absorbed in breaking the test piece, at a lesser rate, this distance registered in foot pounds is obtained from the position of the pointer moved by the pendulum being read on the dial above the machine.

55. What Size is the Test Piece used in the Impact Test?

6 × $\frac{7}{8}$ × $\frac{7}{8}$ in., the test piece having a saw cut 3 in. from the end $\frac{5}{16}$ in. deep with $\frac{1}{8}$ in. radius at the end of the cut. It is positioned in the vice with the saw cut facing the tup and level with the top of the vice, the tup striking the test piece $2\frac{1}{2}$ in. from the saw cut. As stated the test piece, i.e. that part coming in contact with the tup, is protected with a steel plate.

56. What is Meant by Density and how is it Calculated ?

The density of timber is the mass per unit volume and is referred to as lb. per cu. ft. The moisture content should always be quoted. The density is calculated by weighing the sample and applying the formula :

$$\frac{12^3 \times W}{ABC}$$

W = weight of sample in pounds.
A = length of sample in inches.
B = width of sample in inches.
C = thickness of sample in inches.

$$\therefore \frac{1728 \times 12}{12 \times 12 \times 6}$$

= 24 lb. per cu. ft. at 17%. Moisture content, 17%.

57. What Factors Govern the Density of Timber ?

Rate of development, moisture content and the part of the tree from which the timber was cut.

58. What other Tests are Carried Out on Timber ?

The compression test and the bend test. From the bend test the moduli of elasticity and rupture are calculated.

59. Name the Advantages of Plywood.

Strength, resistance to splitting, and pliability. It is not susceptible to shrinkage.

60. Explain the Construction of Plywood.

Plywood generally consists of three veneers glued together, the grain of the outer veneers running at right-angles to the grain of the inner veneer. The veneers are dried to a moisture content of 10%. Glue is spread on the inside of the two outer veneers and these are placed above and below the core. The layers are then placed in a press, the press having flat surfaces which are heated by steam circulated through the plate at 200° F. approx. This heat sets the glue.

61. When there are More than Three Veneers Glued Together what Name is given to the Wood?

"Multiply."

62. What Timbers are used in the Construction of Plywood?

Mahogany, birch or teak are mostly used for outer veneers. Birch, mahogany, basswood, whitewood or poplar are used for the inner veneers.

63. Explain how a Sheet of Plywood should be Examined for Defects.

Ensure that the plies are securely connected together, that the sheet is flat, free from buckling, blisters, wrinkles, gaps, overlaps and that the joins comply with specification, ensure also that the edges are square and that the surfaces are free from defects.

64. What is Stamped on a Sheet of Plywood passed by the Inspector?

Inspector's stamp, batch number, names of the timbers used for the veneers and the date of manufacture.

65. Why is the Date of Manufacture Important?

Plywood which has been stored for a period of twelve months or more must be retested before being used in aircraft.

66. Name the two Classes of Plywood used for the Construction of Aircraft.

1. Plywood used for structurally important parts.
2. Plywood used for subsidiary parts.

67. What Tests are Carried Out on Plywood used for Structurally Important Parts?

Resistance to water, resistance to dry heat, moisture content, and adhesion of the veneers.

68. What is the Test for Adhesion of the Veneers?

The test piece is 6 in. long, 1 in. wide, with a saw cut across the test piece on either side. These saw cuts are through two of the plies and are 1 in. apart or 8 times the thickness of the plywood, whichever is the smaller. The glue must have a strength at least 200 lb. per sq. in. of the glued surface, and the mean of three test pieces is taken.

69. Should the Fracture be Clean when Adhesion Tested?

No. The fractured surfaces should have fibres of the wood adhering to the glued surfaces.

70. What is the Test for Moisture Content?

This is tested for in the same way as in ordinary timber, except that the test piece is not dissected.

71. What is the Test for Resistance to Water?

Two test pieces are prepared (9 in. × 4 in.), and immersed in boiling water for 3 hr. No sign of separation of the plies should occur. One of the test pieces on completion of the test is plunged in cold water and while still wet should have an adhesive strength not less than 100 lb. per sq. in. of glued surface.

72. What is the Test for Resistance to Dry Heat?

The test piece is dried for 3 hr. at 100° C. and should show no sign of separation or blisters.

73. How should Timber be Stored?

Timber parts should be stored in a well-ventilated storeroom at a temperature 60° F. Plywood must be weighted.

74. How is Glue Tested for Strength?

Two pieces of black walnut 2 in. wide are glued together with the glue to be tested, the joint being formed by overlapping the two pieces 1 in. After allowing the glue to set, the joint must have a tensile strength of at

least 1,100 lb. per sq. in. A similar test piece is placed in water for 3 hr., dried for half an hour and the joint should then have a strength of at least 1,000 lb. per sq. in.

75. What is Casein Cement?

A cold glue, obtained from Switzerland, India, and other countries. It consists of milk treated with acid. The milk coagulates, is dried and ground, and then mixed with other ingredients, producing a white powder which is the casein cement.

76. What Precautions are Taken when using Casein Cement?

The cement is mixed with cold water, and owing to the different ingredients, the powder should be well shaken before mixing. The proportion of water to cement is very important and the instructions of the maker must be strictly adhered to, otherwise the cement will give inferior results. The cement must be made up freshly each day ; cement left over from the previous day must be discarded.

77. What Defects may be Found in Wooden Components?

Brittleness or shrinkage, compression shakes, damage caused by insects, crushing of the fibres, and oil soakage.

78. What is Brittleness or Shrinkage?

These defects occur owing to the drying out of the moisture. Slackness of metal fittings or the breaking down of glued parts or joints must be thoroughly inspected to ensure they are not due to the above defects.

79. What are Compression Shakes?

These may be present if the part has suffered severe shock (likely to be caused through a heavy landing). This defect can be seen by examining the varnish on the member which will crack across the fibres of the wood.

80. How is Damage Caused by Insects Indicated ?

It is indicated by small holes in the timber surface. Timber parts in storage should be inspected for this defect.

81. How is Crushing of the Fibres Caused ?

This can also be caused by a heavy landing, though the overtightening of the bolts holding the fittings to the member is another cause.

82. How can Oil Soakage be Prevented ?

By ensuring that the parts are well protected with their respective protective coating in the vicinity of the engines and oil tanks.

METALLURGY TERMS

83. What is Brittleness?

The tendency of a metal to fracture on receiving a blow.

84. What is Specific Gravity?

The specific gravity of a metal is the ratio of any volume of it, to the weight of an equal volume of pure water at 4° C.

85. What is Malleability?

That tendency of a metal to extend or flatten when worked under the hammer or rolls.

86. What is Toughness?

The resistance which a metal offers to breaking after the elastic limit has been passed.

87. What is Tenacity?

That property of a metal to resist fracture when under the application of a tensile force.

88. What is Softness?

The tendency to permanently yield to pressure without fracture.

89. What is the Elastic Limit?

When the external force causing distortion passes beyond a certain limit the metal does not return to its original shape on removal of the force. This point is called the elastic limit.

90. What is Hardness?

That tendency of a metal to be able to cut, scratch or indent another metal, or may be described as the property of resisting wear by abrasion.

91. What is Fusibility?

The capability of being melted. All metals are fusible.

92. What is Tensile Strength?

It is the resistance, generally quoted in tons per square inch, which is offered by a metal to the pulling-apart tendency produced by a tensile stress.

93. What is Elasticity?

It may be defined as the capacity of a metal to return to its original size or shape after distortion by an external force.

94. What is Fatigue?

A weakening or collapse of metals due to the continuous application of alternating or varying stresses.

95. What is Conductivity?

The ability of a metal to conduct heat or electricity.

96. What is Meant by "Refractory"?

Any substance that does not easily melt is said to be refractory. Furnaces are lined with a refractory clay.

97. What is Meant by "Ductility"?

A metal is said to be ductile when it is capable of being permanently elongated—i.e. drawn into the form of wire, etc.

PRODUCTION OF IRON AND STEEL

98. What is the First Process in the Manufacture of Iron and Steel?

The Blast Furnace. Iron ore quarried or mined, with the addition of limestone and coke, is subjected to high temperature in the blast furnace through the burning of the fuel and by a high pressure air blast. The molten metal and slag collect at the bottom. The metal is tapped and run off. The slag being lighter floats on top and is run off or overflows through a small aperture left for this purpose. The metal run off from the blast furnace is known as pig iron or pig.

99. What is Cast Iron?

Large quantities of pig iron are simply remelted in a small blast furnace known as a cupola, the composition of the resulting cast iron being obtained by blending various brands of pig iron, etc.

100. Why is it that Cast Iron with its High Carbon Content cannot be used for Tools?

Owing to the high carbon content, cast iron has little mechanical strength, the material being very brittle.

101. What is the Carbon Content of Cast Iron?

2·5 to 4·5%.

102. What Influence has Silicon on the Properties of Cast Iron?

When the silicon content is high, the cast iron is more fusible, but it is softer, and its mechanical properties are weaker. If the silicon content is low, the metal is less fusible, but very hard and strong. Silicon has the property of influencing the carbon in the iron. When much silicon is present a high percentage of the carbon

will be in a free and graphitic state, but when the silicon is low a high percentage of the carbon will be in the combined state.

103. What is White Cast Iron?

This metal is exceptionally hard and its wearing qualities are good. Combined carbon predominates.

104. Is Grey Cast Iron Softer than White Cast Iron?

Yes. The carbon content is made up chiefly of graphitic carbon.

105. What is Meant by Mottled Cast Iron?

This grade of cast iron comes between the two previously stated, and it has medium hardness and strength. The carbon is equally graphitic and combined.

106. How are Malleable Iron Castings Produced?

Iron castings made in the ordinary way are very brittle, and are made relatively stronger and more malleable by subjecting the castings to long annealing, usually from 7 to 10 days.

107. What is Meant by a Chill Casting?

Iron castings are usually made in sand moulds, but if the mould or part is made of iron, when the metal is poured, that coming in contact with the metal part of the mould will suddenly cool, the carbon being trapped in the combined state to a certain depth of the casting. In the casting of sections of variable thickness cast iron rods are sometimes placed in the sand mould to conduct the heat from the thicker sections so that the rate of cooling the whole section is more or less even.

108. How is Steel Produced?

Structural steel is produced by the purification of the pig iron, which usually contains a large percentage of impurities. The impurities, including the carbon, are removed by an oxidation process. The strength and hardness of plain carbon steel is governed by the percentage of carbon in the finished steel.

109. Explain the Open Hearth Process.

A mixture of scrap and pig iron is melted in a shallow hearth by means of producer gas. To attain the high temperature required both gas and air are usually preheated. After melting the charge and seeing that it is completely covered with slag, pure hematite ore, or mill scale is added to render the slag oxidizing, and by interacting with the impurities eliminates them. The steel is run down dead mild and then recarbonized, but a common practice is to take a sample of the steel which is fractured and to judge the carbon content, then catch the carbon at the desired percentage.

110. Explain the Bessemer Process.

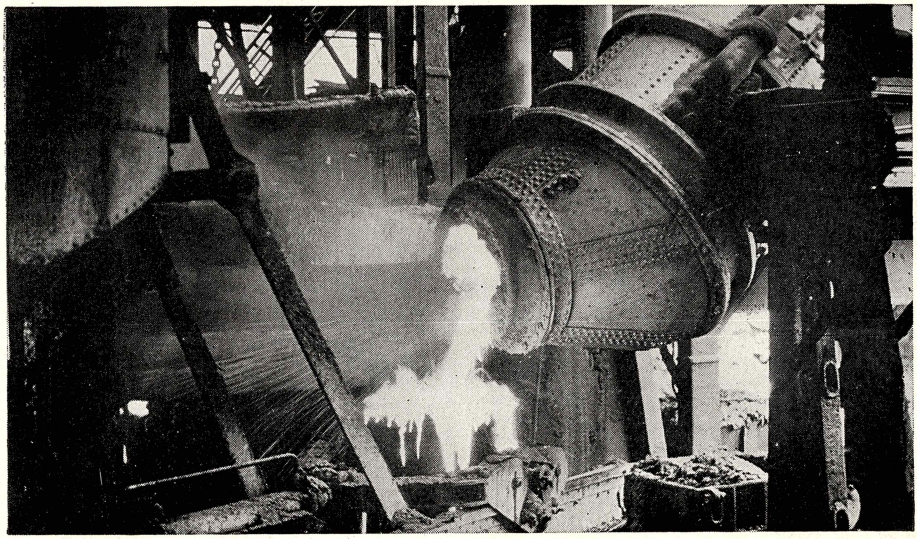
The iron ore is melted in the blast furnace and the molten metal is then transferred to a large pear-shaped vessel called a converter. The impurities are oxidized and removed by blowing air at a high pressure up through the molten metal. The combustion of the carbon, silicon and manganese afford sufficient heat to keep the resulting metal molten.

111. What is the Disadvantage of the Electric Process?

This method is expensive and consequently efforts have been made to overcome this difficulty by first partly purifying the metal by the open hearth or bessemer process, and then transferring the molten metal to the electric furnace for the final treatment. The most commonly used electric furnaces are basic hearths heated by arcs from carbon electrodes placed above the hearth. The process lends itself to the production of high quality steels, and very low sulphur steel can be produced with ease.

112. How is Wrought Iron Produced?

The pig iron is subjected to the puddling process. The pig iron is melted in a furnace, but remains in a pasty condition mixed with slag. It is then made up into spongy balls which are removed from the furnace,



[*Practical Mechanics*

MOLTEN STEEL BEING MECHANICALLY POURED FROM A BESSEMER "CONVERTER" INTO WAITING POTS

squeezed, hammered, and finally rolled, most of the slag being expelled during the hammering. Wrought iron fractured is very interesting, the fracture being similar to a break in a green piece of timber. Owing to its fibrous nature the slag can be easily seen. Carbon content of Wrought iron is up to ·2%.

113. Explain the Cementation and Crucible Process.

Wrought-iron bars are packed in airtight boxes with wood charcoal. The furnace is kept at a high temperature for between 5 and 11 days and then allowed to cool down. The bars are then known as " Blister " steel as they are covered with blisters. The object of this treatment is to increase the carbon content with the exclusion of impurities.

114. What is Tool Steel?

Tool steel is usually produced by melting the blister bars in a covered crucible and making into ingots. This type of steel is of very high quality. When speaking of cast steel, used in the manufacture of tools, what is generally referred to is steel made in the crucible, which has a carbon content of at least ·7%.

115. What Elements are Added to Carbon Steels?

Nickel, chromium, vanadium, tungsten, cobalt, molybdenum and manganese.

116. Why is Nickel Added?

Because it increases the toughness and raises the elastic limit. When the nickel content is over 27% the steel is non-magnetic and almost non-corrodible. and it also has a very low coefficient of expansion.

117. Why is Chromium Added?

Because it imparts greater hardness, better wearing qualities, and also confers air-hardening qualities. Steel is " stainless " when the chromium content exceeds

12%. When containing over 6% nickel and 12% chromium, besides being " stainless " the steel is non-magnetic, and is termed " Austenitic " steel.

118. Why is Vanadium Added ?

It is added to impart fatigue-resisting qualities, and also toughness. Valve springs and oleo springs are made from this steel. An addition of ·2% vanadium will increase the toughness and elastic limit of low-carbon steel by 50%.

119. Why is Tungsten Added ?

Because it retains its strength and hardness at dull red heat, and also imparts air-hardening qualities. This steel is used for exhaust valves, high speed cutting tools, etc.

120. Why is Cobalt Added ?

Because it eliminates scaling at high temperatures and has air-hardening properties.

121. Why is Molybdenum Added ?

Because it has a similar influence on steel as tungsten, but four times more intense. It also prevents temper brittleness.

122. Why is Manganese Added ?

Manganese has the property of imparting exceptional hardness to low carbon steel. A steel of this class with 12% magnanese, when quenched in water from 950° C., will be soft and ductile, but if the surface of the steel is cold worked it will very quickly work harden, the core remaining soft and ductile. A small percentage of manganese is allowed in steel, used for tubes in welded structures. Manganese neutralizes the effect of impurities in the weld.

THEORY OF HEAT TREATMENT (PLAIN CARBON STEEL)

123. What is the Object of Heat Treatment?

It gives the steel definite mechanical and physical properties.

124. Explain the Term *Straight* or *Plain* Carbon Steel.

This denotes that the steel owes its qualities to an addition of carbon.

125. If the Steel owes its Qualities to Elements other than Carbon, how is it Designated?

As alloy steel.

126. Name the Constituents of Plain Carbon Steel.

Iron (Ferrite) and iron carbide (Cementite).

127. Explain the Term "Eutectic."

If a substance is Eutectic it denotes that its constituents, when intimately mixed, are in such proportion to one another that when melted the mixture will have a lower melting point than if the constituents were melted separately. Eutectoid is the same phenomena occuring in the solid mass. Pearlite is the eutectoid of steel. Solder is eutectic when the percentages of tin and lead are respectively 66% and 34%. This solder has a melting-point 181° C. approx.

128. Explain the Term "Solid Solution."

A solid solution is a homogeneous mixture of two or more substances in the solid condition.

129. What are Ferrite and Cementite?

Ferrite is pure iron, very soft and weak. Cementite is iron carbide, very hard and brittle—93·4% iron; 6·6% carbon.

130. What is the Decalescence Point?

It is that temperature at which, when heating steel, the iron completely dissolves the iron carbide and forms a solid solution.

131. Explain the Recalescence Point.

If the steel is heated above the decalescence point and allowed to cool very slowly, it reaches a temperature known as the recalescence point, when the iron carbide falls out of solution and pearlite begins to form.

132. What is the Carbon Content of Pearlite?

·89%. The structure consists of ferrite and cementite arranged in strata or layers.

133. If the Steel contains less than ·89% Carbon and was Cooled Slowly from the Upper Critical Point what Type of Structure would be Formed?

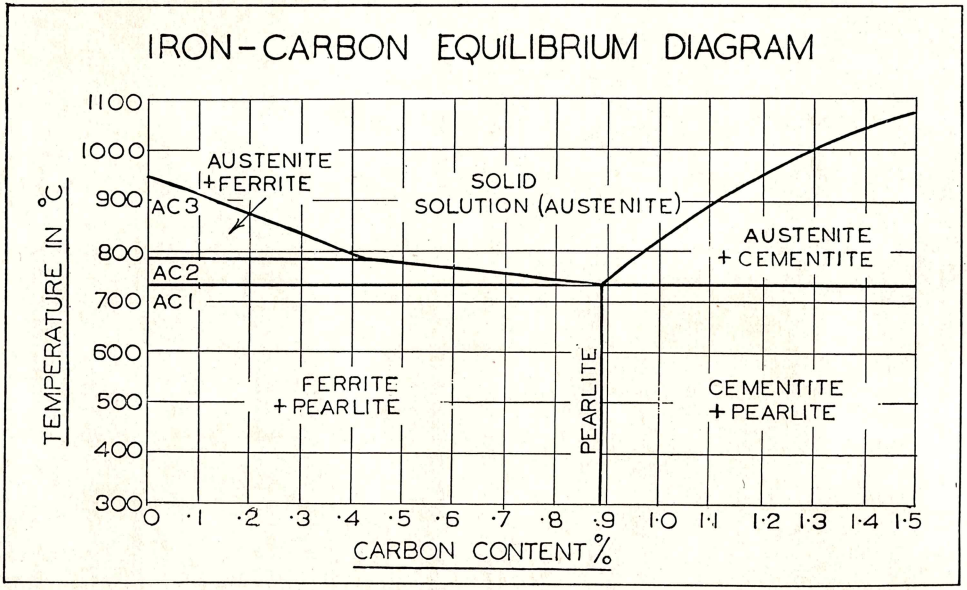
The structure would consist of pearlite crystals surrounded with free ferrite.

134. If the Steel contains over ·89% Carbon and was Cooled Slowly from the Upper Critical Point what Type of Structure would be Formed?

The structure would consist of pearlite crystals surrounded with free cementite.

135. What is Meant by Upper Critical Point?

It is that point (temperature) when the iron and carbon dissolve completely into one another and form the solid solution.


IRON-CARBON EQUILIBRIUM DIAGRAM
TEMPERATURE IN °C
1100
1000
900
800
700
600
500
400
300
AUSTENITE
+FERRITE
AC3
AC2
AC1
SOLID
SOLUTION (AUSTENITE)
AUSTENITE
+ CEMENTITE
FERRITE
+ PEARLITE
PEARLITE
CEMENTITE
+ PEARLITE
0 ·1 ·2 ·3 ·4 ·5 ·6 ·7 ·8 ·9 1·0 1·1 1·2 1·3 1·4 1·5
CARBON CONTENT %

136. The Critical Points are Shown as AC_1, AC_2, AC_3. Explain what this Means.

It shows the arrest points on a rising temperature—i.e. that a structural change of the steel has taken place at these temperatures.

137. What is meant by the Term "Allotropic"?

That the physical properties are different without change of substance.

138. What are the Allotropic Forms of Iron?

Alpha—stable below the AC_2 point. Magnetic.

Beta—stable between the AC_2 and AC_3 points. Non-magnetic.

Gamma—stable above the AC_3 point. Non-magnetic.

Delta—refers to melted iron.

139. What is Martensite?

If steel is heated above the carbon change point and quenched in water the constituents are trapped in the combined state. The resultant structure is termed Martensite, which is magnetic, glass-hard and brittle.

140. Explain the Term "Austenite."

Austenite is the structure formed when heating steel above the carbon change point. In this state the steel is soft and non-magnetic.

141. Why does Steel Change from Austenite to Martensite when Quenched in Water?

Because the cooling rate is not fast enough to trap the steel in the Austenitic state as the iron changes its allotropic form from Gamma to Alpha iron.

142. Is Austenitic Steel a Commercial Proposition?

Yes, if certain elements are added to the steel. A steel of this class termed "Staybrite" has a nickel content 8% and chromium content 18%. It is non-magnetic and almost non-corrodible. Owing to the

high percentage of nickel and chromium the steel whether quenched or allowed to cool in the air will remain austenitic. The nickel has the property of slowing down the change point to such an extent that it is below atmospheric temperature.

143. How can Austenitic Steel be made Magnetic?

By cold working, or by freezing at a very low temperature.

144. Explain the Terms "Sorbite" and "Troostite."

These are different structures obtained by cooling the steel at a rate less than the critical rate from above the upper critical point, or by tempering.

145. What Occurs at the AC_2 Point?

At this temperature steel becomes non-magnetic.

146. What is an Hypo-Eutectoid Steel?

Steels containing less than ·89% carbon are termed Hypo-Eutectoid steels. If the carbon content is above ·89% the steel is termed Hyper-Eutectoid.

HEAT TREATMENT (PLAIN CARBON STEEL)

147. Will Carbon Increase or Decrease the Melting Point of Steel?

Carbon will decrease the melting point.

148. Why is Steel Annealed?

To induce softness, refine the crystalline structure or relieve internal stresses.

149. How is Steel Annealed?

Heat to 30° C. above the AC_3 point and allow job to cool down very slowly with the furnace.

150. What is the Object of Close Annealing?

The object is the same as that of ordinary annealing, but this treatment preserves the surface of the steel from oxidation or decarburization.

151. What Governs the Temperature for the Heat Treatment and how can the Best Temperatures for any Class of Steel be Found?

Carbon content. Information as to the best temperatures will be supplied by the steel maker.

152. Explain the Normalizing Treatment.

The steel is heated from 870° C. to 900° C., and allowed to cool in still air.

153. Why is Steel Normalized?

So that the internal stresses set up by previous heat treatment or cold working will be relieved and the steel therefore restored to its normal condition.

154. Why, when Normalizing, is the Steel Maintained at the Temperature 900° C. Approx. for about 15 Minutes and not Allowed to Exceed the Upper Critical Range by 30° C ?

So that the heat penetrates to the centre, and to eliminate excessive crystal growth.

155. What Influence has the Size of the Crystal Grains ?

Generally the smaller the grain size, the greater is the toughness and tensile strength of the steel.

156. Why is Steel Sometimes Heat Treated by the Low-Temperature Normalizing Method ?

This method is used as it eliminates distortion, also excessive scaling and consequently serious reduction of area which would be detrimental to thin-gauge material.

157. Explain the Low-Temperature Normalizing Method.

The job is placed in a salt bath at 550° C. approx., and allowed to soak for a definite period—the time is governed by the size and thickness of the job—it is then removed and cooled in still air.

158. Is the Object of the Two Normalizing Methods the Same ?

Yes.

159. Why is Steel Tempered ?

When steel is heated above the upper critical point and quenched in water to harden, the steel will be very brittle. To relieve this brittleness and induce toughness the steel is tempered.

160. How is Steel Tempered ?

After being hardened, the steel is reheated to a temperature generally below the AC^1 point.

161. What Governs the Tempering Temperature ?

The purpose for which the steel is to be used.

162. Give the Approximate Temperatures Employed when Tempering Tool Steel?

180° C. to 300° C.

163. Why are these Temperatures not very High?

It can be understood that tool steel must be very hard with a minimum of brittleness.

164. How can the Approximate Temperature be Ascertained when Tempering Steel in the Open Hearth?

By the oxide colours forming on the steel.

Tempering colours approx. temperatures:

Pale yellow	220° C.
Straw	230° C.
Golden yellow	243° C.
Brown	255° C.
Dark brown	265° C.
Purple	277° C.
Bright blue	290° C.
Pale blue	297° C.
Dark blue	315° C.

165. Can Steel be Hardened Below 900° C?

Yes, if the carbon content is ·89%. (Pearlite is the eutectoid of steel, critical points 730° C. approx.)

166. Why is Steel Hardened?

So that the steel will be more resistant to wear by abrasion.

167. How is Steel Hardened?

It is heated to 30° C. above the AC_3 point and quenched in water.

168. How is it Possible to Ascertain when Heating Steel in the Open Hearth, that the Temperature is Sufficient to Harden the Steel (if Quenched)?

Steel heated above the carbon change point is non-magnetic.

169. Can Mild Steel be Hardened?

Not sensibly, as the carbon content is insufficient.

170. How can Mild Steel be Made more Resistant to Abrasion?

By case-hardening.

171. Explain the Theory of Case-Hardening.

When the metal is heated to redness in a box packed with the carburizing compound, gases are evolved. The carbon gases gradually penetrate the metal converting it to a certain depth into high carbon steel, while the core remains in its original state.

172. Why is Carbon Added to Iron?

To increase the tensile strength and hardness.

173. Will Case-Hardening Increase the Tensile Strength of Mild Steel?

Not appreciably, as the core will remain soft and tough.

174. What is Meant by Mild Steel?

Mild steel is that which contains up to ·25% carbon.

175. Instance and Explain a Case-Hardening Process for Plain Carbon Steel.

The Sealed Box method:

The job is placed in a box and packed with the carburizing compound, sealed and placed in the furnace for about 4 hours at a temperature of 900° C. The box is then removed and the job allowed to cool before unpacking. To refine the core the job is reheated to 900° C and quenched. To harden the case the job is again heated (to 760° C.) and quenched in water or oil.

176. Why is the Core Refined?

Owing to the prolonged heating the structure is very soft, coarse, and therefore weak, crystal growth having taken place. This operation restores the structure to its normal condition.

177. If it is Necessary to Case-Harden a Part of a Job, what Steps can be taken to Ensure that the Remaining Portion is not Treated?

The portion not to be case-hardened can be protected by copper deposition and covering with fire clay.

178. What is the Carbon Content of Medium Carbon Steel?

·25% to ·7%.

179. What Should the Depth of Case be when Case-Hardening by the Sealed Box Method?

1 mm. (·039 in. approx.)

180. How should Steel be Case-Hardened in the Open Hearth?

The steel is heated to redness, and dipped in a carburizing compound. The job is then replaced and again heated for a few minutes. This operation is generally repeated three times. Any compound which adheres after the final dipping must be cleaned off and the job reheated to a medium red and then quenched in water to harden the case. The depth of case is approx. ·005. in.

181. What is the Carbon Content of High Carbon Steel?

·7% to 1·5%.

182. How are the High Temperatures Measured when Heat Treating Steel?

By pyrometer or sentinel cones.

183. What are Sentinel Cones?

They are pyramids of metallic or mineral substance, which have a definite melting point. Tests have proved this method to be accurate to 5° C.

184. Explain the Nitrided Process.

This process is case-hardening by means of nitrogen, generally applied to alloy steel. The job is placed in a stainless steel box heated at 500° C. approx. for between 20 and 90 hr., and dry ammonia gas injected. The ammonia is decomposed and nitrogen absorbed by the steel. The abrasive resistance is then five to ten times that of the carbon case.

185. Why will Steel sometimes Crack during Heat Treatment?

Cracks are due to internal stresses set up when heating steel to a high temperature and subsequent cooling at a fast rate.

186. Why must the Job be Agitated when Quenching?

The steel is kept moving, otherwise bubbles of steam may collect on the surface and greatly retard the cooling rate. When the steel has to be partially quenched this agitation also eliminates any water line.

187. Name Three Methods of Tempering Steel.

The salt bath, oil bath, and alloy bath. Any of these methods can be used.

188. What Defects should be Looked for in Steel Bar?

Roaks, piping, laps, cracks, seams and draw marks.

189. How is Piping Caused?

It is due to the centre of the ingot solidifying at a slower rate than the outside, with the result a cavity is formed in the centre of the ingot. Parts made from the centre of the ingot including this cavity, which will be hard to detect in the rolled condition, would be a source of weakness.

190. What is a Lap?

A lap is the flash or fin being worked into the bar during rolling.

191. How would an Inspection for Cracks be Conducted?

With the aid of a magnifying glass, or by soaking the part in paraffin, wiping dry, and coating with french chalk. A crack will be denoted by paraffin showing on the chalk.

192. How are Seams Caused?

They are due to surface cracks or blowholes. Gas trapped in the ingot when solidifying forms blowholes.

193. How can Blowholes be Detected if not Seen from the Outside of the Material?

By radiological examination.

194. How are Roaks Formed?

They can be caused by slag, or the decarburized surface being pressed into the steel and drawn out during rolling.

195. What Type of Defect is Formed by Draw Marks?

This defect is caused through dirt or foreign matter being worked into the surface of the metal by the dies during the drawing operation, with the result that the metal may be scored and the marks closed by subsequent rolling.

196. What Defects should be Looked for in Sheet Material?

Buckles, blisters, laminations, cracks, and incorrect gauge.

HEAT TREATMENT (DURALUMIN)

197. What is Duralumin ?

An aluminium alloy, consisting of 3·5 to 4·5% copper, ·4 to ·7% manganese, ·4 to ·7% magnesium, iron and silicon impurities, the remainder being aluminium.

198. At what Temperature should Duralumin be Annealed ?

350° to 420° C.

199. Can Duralumin be Bent other than in the Annealed Condition ?

Yes. The bend radii are governed by the condition of the duralumin, i.e. normalized or age-hardened condition.

200. May Duralumin be Normalized in the Open Hearth ?

No, since the temperature cannot be controlled.

201. Steel can be Normalized or Annealed at the same Temperature. Does this also apply to Duralumin ?

No, the normalizing temperature for duralumin is 490 $\pm$ 10° C.

202. Why is the Salt Bath used to Heat Treat Duralumin ?

Salt baths are used because the temperature is even and controlled. Also because the salt has a high evaporation point, is clean, and not detrimental to the duralumin providing it is washed off.

203. What Salt is used in the Salt Bath?

Generally 50% sodium nitrate plus 50% potassium nitrate.

204. Suppose the Job being Normalized is too large to be Submerged in the Salt Bath. Can Double Immersion be Carried out?

No.

205. Why should Duralumin always be Normalized after Annealing?

Duralumin in the annealed condition is weak and more liable to corrode. It has to be normalized so that it will return to its maximum strength and hardness by age-hardening.

206. Explain the Term "Age-Hardening."

Normally the amount of copper aluminium can absorb is between 1% and 2%, but on being heated as much as 4% to 5% can be absorbed. This phenomena also occurs with magnesium which combines with the silicon. When heated the copper and magnesium are retained in the solid solution but after quenching the excess copper and magnesium is precipitated around the crystal boundaries, causing resistance to deformation by slip. When the duralumin is quenched it is soft and ductile, but the strength and hardness increases as stated above. This phenomena is termed age-hardening. It is completed 4 to 5 days after normalizing, and the duralumin will then be at its maximum strength and hardness. It must be mentioned that annealed duralumin hardens but not to the same extent as normalized duralumin.

207. Should Duralumin be Allowed to Cool in the Air after Normalizing?

No. Duralumin must be quenched in clear cold water, the water tank being close to the salt bath, so that when the duralumin is quenched it is still 490 $\pm$ 10° C.

208. Should Duralumin be Quenched after Annealing?

It can either be quenched or allowed to cool in the air. If cooled in the air the salt must then be washed off.

209. May a Built-up Fitting be Normalized in the Salt Bath?

No. Severe distortion will be set up, and also the salt will be impossible to remove between the joints; therefore corrosion will occur.

210. Can Duralumin be Heat Treated by Methods other than the Salt Bath?

Yes, in a muffle or furnace, on condition that the temperature is even and controlled.

211. If a Fitting were made of Duralumin and Fitted to the Aircraft in the Annealed Condition would it be Serviceable?

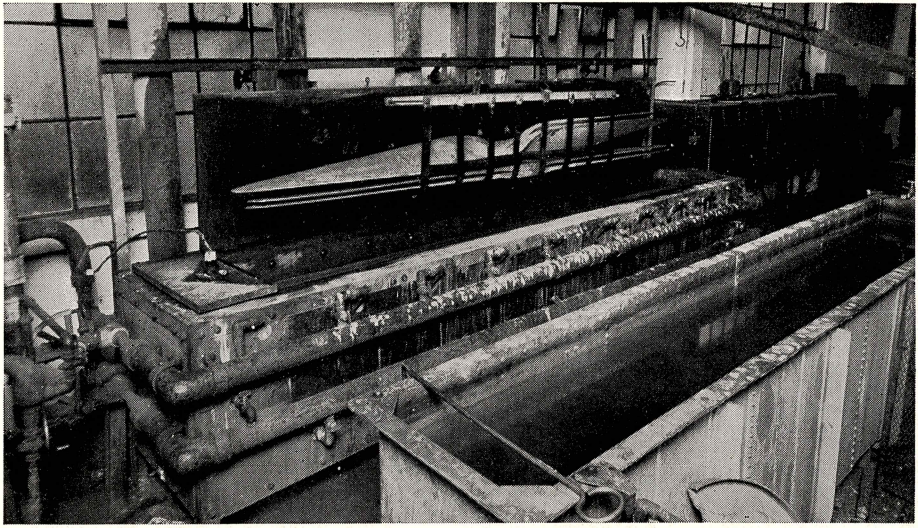
No. Annealed duralumin will not fully age-harden, therefore the fitting would be weak, and also more liable to corrode.

212. How soon may Rivets be Used after being Normalized?

Duralumin rivets can be formed without fracture if used within one hour. This time is extended to two hours in some aircraft factories.

213. What is the Procedure for Normalizing Duralumin Rivets?

Check the temperature of the bath ($490 \pm 10°$ C). Place the rivets in a small receptacle, having holes to allow the molten salts to drain, attach to a piece of wire and suspend in the salt for 20 min. This time allows 5 min. for the rivets to reach the temperature of the bath. Remove and quench instantly in clean cold water.



SALT BATH USED FOR ANNEALING AND NORMALIZING DURALUMIN AIRSCREWS

214. Why should the Temperature of 500° C. Never be Exceeded when Heat Treating Duralumin?

Owing to its relative low melting point, burning of the constituents may occur above this temperature.

215. What are the Minimum Permissible Radii for Bending Duralumin?

	Annealed	Normalized (within 1 hr.)	Age-hardened
Below 22. S.W.G.	$\frac{1}{2}$	$1\frac{1}{2}$	$2\frac{1}{2}$
Above 22. S.W.G.	1	2	3

× the thickness of the material.

216. Can the Age-Hardening Period be Reduced?

Yes. This method is not generally applied to aircraft parts as this treatment reduces the corrosion-resisting properties of duralumin. After normalizing and quenching in cold water, the parts are placed in boiling water for two hours.

217. Is the Tensile Strength of Duralumin in the Normalized Condition much below that of Age-Hardened Duralumin?

50%.

218. How can Duralumin Rivets in the Normalized Condition be kept in this state for Periods Greater than One Hour?

Age-hardening can be retarded by keeping duralumin — 15° C. It is thus entirely suppressed for 168 hr. and only continues at a reduced rate for even longer periods. The normalized rivets are packed in small tins and kept in a box surrounded with carbon dioxide ice.

219. Are Castings made of Duralumin?

No.

NON-FERROUS METALS AND ALLOYS

220. What is Meant by the Term "Non-Ferrous"?

That the metal has a base other than iron.

221. What is Monel Metal?

A nickel base alloy containing 29% approx. copper. Its melting point is 1,350° C. approx. It is non-corrodible and almost non-magnetic. Its mechanical properties depend upon the cold working to which it has been submitted. It has great strength and toughness retaining these characteristics to an appreciable extent up to a temperature of 400° C.

222. What is Duralumin?

An alloy which has a base of aluminium, containing copper, manganese and magnesium, impurities, iron and silicon. It can be supplied in the form of sheets, tubes, bars and forgings, but it is not suitable for castings. In the finally heat-treated condition it has a strength equivalent to mild steel but its specific gravity is about one third of same.

223. What is Alclad?

It is duralumin coated with aluminium, and has the corrosion resistance of aluminium but almost the strength of duralumin. The combined thicknesses of the layers of aluminium is approx. 5% of the whole. Alclad is used for stressed skin construction.

224. What is Alpax?

It has a base of aluminium, containing 10% to 14% silicon (silicon promotes fluidity). Its specific gravity is lower than that of aluminium but its strength is about double of same. It is used for castings and has good resistance to corrosion.

225. What is Elektron?

It has a base of magnesium. D.T.D. 88B. contains 10% approx. aluminium, 1·5% approx. zinc, 1% approx. manganese. This alloy can be supplied in the form of extruded rods, bars, angles, sheets, tubes, forgings and also castings. It has a very low specific gravity, and its tensile strength ranges from 15 to 22 tons per sq. in. If two fittings are made to identical dimensions, one of ordinary aluminium alloy, the other Elektron, the Elektron fitting would be only 60% of the weight of the other.

226. What is "Y" Alloy?

It has a base of aluminium, containing copper, nickel and magnesium. This alloy is similar to duralumin but possesses the advantage of being easily cast, and can also be forged.

227. What is Hiduminium?

It has a base of aluminium containing copper, nickel, magnesium, iron, titanium and silicon. Has exceptionally fine grain crystalline structure. Can be forged and cast, and has also a very high resistance to corrosion. After heat treatment its strength is above that of mild steel.

228. What is M.G.7?

It has a base of aluminium, containing magnesium and a small percentage of manganese. It is as light as aluminium but its strength is about double that of same. It has high resistance to inter-crystalline corrosion. No heat treatment is necessary to produce maximum strength of soft sheets. It can also be welded without destroying the strength of surrounding material. It can be forged and cast.

229. What is Soft Solder?

An alloy of tin and lead, bismuth added to reduce the melting point. Grade "A" solder contains 66% tin and 34% lead. Grade "B" solder contains 50% tin

and 50% lead, melting points respectively 181° C. and 206° C.

230. What is Brass?

An alloy of copper and zinc.

231. What is Bronze?

An alloy of copper and tin.

232. What is Phosphor Bronze?

An alloy of copper, tin and phosphorus.

233. Describe Aluminium.

It is tin white in colour, and melts at 658° C. approx.

234. Describe Lead.

It is dull bluish white in colour, and melts at 328° C. approx.

235. Describe Tin.

It is white in colour, and melts at 232° C. approx.

236. Describe Copper.

It is reddish brown in colour, and melts at 1,085° C. approx.

237. What is Chromium?

A hard grey metal, which melts at 1,620° C. approx.

238. Describe Nickel.

It is silver-white in colour, and melts at 1,450° C. approx.

239. Describe Zinc.

It is blue-white in colour, and melts at 418° C. approx.

TESTING METALLIC MATERIALS

240. Define Hookes' Law.

Hookes' law refers to the relationship between stress and strain. If the load is withdrawn within the elastic range of the material, the material will return to its original dimension.

241. Define Stress and Strain.

Stress is the load or force the material has to bear, generally expressed in tons per square inch of cross-sectional area.

Strain is the extension of the material produced by the stress and expressed as elongation per unit length.

242. When is the Elastic Limit Passed?

The elastic limit is passed when the stress produces a permanent set in the material. At this point Hookes' law breaks down.

243. What is the Yield Point?

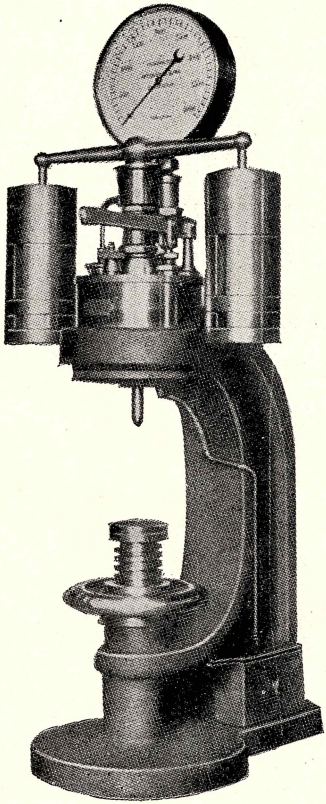
After passing the point known as the elastic limit, a sudden extension occurs with little or no increase in stress and is referred to as the yield point. The stress is termed the yield stress.

244. Why is the Yield Point not of great Importance?

As the material has passed the elastic limit a permanent set has occurred. The designer bases his calculations on the strength of materials up to the elastic limit.

245. Will the Yield Stress denote the Tensile Stress of the Material?

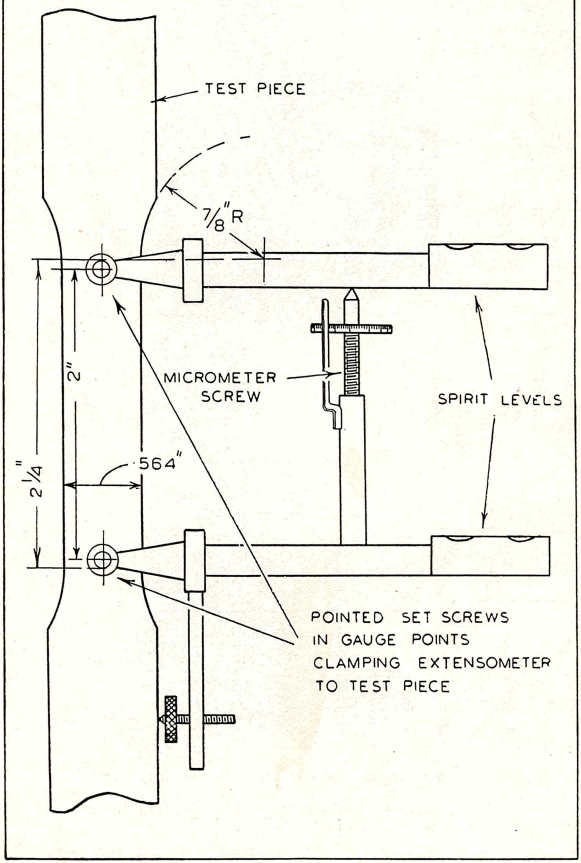
No.



[*By courtesy of J. W. Jackman & Co., Ltd.*

THE STANDARD 3,000 KG. BRINELL HARDNESS TESTING MACHINE

EXTENSOMETER
(MICROMETER SCREW TYPE)



246. Explain Tensile Strength.

The tensile strength of a metal is the absolute strength of the metal under tension, being the force actually required to fracture the metal.

247. How is Tensile Strength Calculated ?

$$\text{Ultimate tensile stress} = \frac{\text{Load at fracture}}{\text{Original cross-sectional area}}$$

and is quoted in tons per square inch.

248. How is the Reduction of Area Calculated ?

It is calculated by measuring the diameter of the test piece at the point of fracture, and expressed as a percentage of the original area.

B = original cross-sectional area in square inches.

b = Area in square inches at the point of fracture.

$$\frac{B - b}{B} \times 100$$

249. If the Material was Bar, what Size should the Test Piece be ?

For bar material $\frac{5}{8}$ to $1\frac{1}{8}$ in. dia., the centre of the test piece is turned down to ·564 in. dia. (as the cross-sectional area will then be ·25 sq. in.) for a distance of $2\frac{1}{4}$ in. The radii at each end of this distance should be at least $\frac{7}{8}$ in. Two light centre pops are marked about the centre of the parallel distance, 2 in. apart, these being the gauge points.

250. What is used in Conjunction with the Gauge Points ?

An extensometer, the two pins of the instrument resting in the gauge points. This instrument is used when accurate information is required regarding the behaviour of the material under test, the extension of the test piece under definite loads being easily readable.

251. How is the Elongation Calculated?

It is expressed as a percentage of the original gauge length. The two fractured portions are fitted together and the distance between the gauge points measured.

l = length between gauge points of broken pieces.

L = original length between gauge points.

$$\frac{l - L}{L} \times 100$$

252. What is Meant by the Term "Limit of Proportionality"?

It is equivalent to the elastic limit.

253. How is the Proof Stress Calculated?

The material is said to have passed the proof stress test if, when the proof stress is applied for a period of 15 sec. and removed, the material has not received a permanent set greater than ·1% of the gauge length.

254. What is the Proof Stress?

The proof stress is the stress at which the stress strain curve departs by ·1% of the gauge length from the straight line of proportionality.

255. What Tests are Applied to Mild Steel?

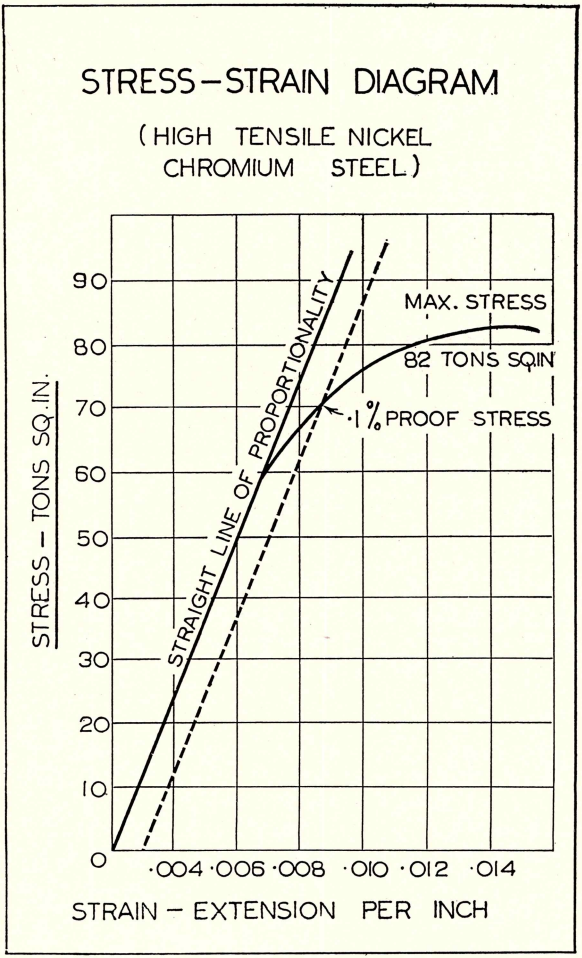
Hardness, impact, tension ; a bend test is also specified if the steel is in the form of sheet or wire.

256. What is Meant by the Brinell Test?

By this test the hardness of the material is calculated. A small hardened steel ball is pressed into the surface of the material under a known pressure ; the area of the impression is then calculated, a Brinell number being obtained from the area of the impression in conjunction with the load applied.

257. Give the Size of the Steel Ball used and Load applied for Steel.

The size of the steel ball is 10 mm. The load applied is 3,000 kg.


STRESS – STRAIN DIAGRAM
(HIGH TENSILE NICKEL CHROMIUM STEEL)
STRESS – TONS SQ. IN.
90
80
70
60
50
40
30
20
10
0
·004 ·006 ·008 ·010 ·012 ·014
STRAIN – EXTENSION PER INCH
STRAIGHT LINE OF PROPORTIONALITY
MAX. STRESS
82 TONS SQ IN
·1 % PROOF STRESS

258. How is the Area of the Impression Calculated ?

By measuring the diameter of the impression with a microscope graduated in millimetres.

259. What is the Duration of the Load and how is it Applied upon the Steel Ball when carrying out this Test ?

The duration should not be less than 15 sec. and the load is generally applied by oil pressure.

260. What is the Formula used to Find the Brinell Number ?

L = Load.
D = Diameter of ball in mm.
d = Diameter of impression in mm.
A = Area of surface of impression.

$$\text{Brinell Number} = \frac{L}{A} = \frac{L}{\frac{\pi D}{2}(D - \sqrt{(D^2 - d^2)})}$$

261. Can the Approx. Tensile Strength of the Material be Found by the Brinell Number ?

Yes. The Brinell number × a known factor = tons per square inch.

The factor for carbon steel is usually ·23.

262. What Precautions are taken when Using a Brinell Machine ?

The material under test must be of sufficient area and thickness to prevent spreading of the material in the vicinity of the impression, otherwise a false value will be obtained. Also the impression must not be applied to highly stressed parts where it will cause the development of cracks.

263. Should very Hard Material, i.e. Case-Hardened Parts, be tested with the Brinell Testing Machine?

Glass-hard or nearly glass-hard material will tend to flatten the steel ball. The Vickers Diamond hardness-testing machine is generally used for these parts.

264. What Advantages has the Vickers Diamond Hardness Test over the Brinell Test?

With this machine the measurement of the impression is recorded directly on to an indicator. Also the impression is very small and therefore this test can be readily applied to finished parts.

265. Explain the Shores Scleroscope.

With this instrument a small diamond-pointed steel pellet of cylindrical form is allowed to fall a fixed height on to the test piece, and the height of its rebound is taken as a measure of the hardness.

266. Has the Turner Sclerometer the same Principle as the Scleroscope?

No. In this test a diamond is drawn across the test piece and is successively weighted until a scratch which can be measured is produced. The weight necessary to produce the scratch is taken as a measure of the hardness.

267. Name some other Hardness Testing Machines.

The Firth Hardometer, and Rockwell and Avery testing machines.

268. What is the Object of the Impact Test?

The chief reason for this test is to ascertain the shock-resisting properties of the steel which are governed by the satisfactory heat treatment or composition of the constituents in the steel.

269. Explain the Impact Test.

The machine used is usually the Izod, and consists of a heavy pendulum swinging in a vertical plane. A vice

is fixed on the bed of the machine in which the test piece is held. The pendulum is clamped in position and when released swings down and breaks the test piece. Owing to the momentum of the pendulum it continues its swing but, as energy has been absorbed in breaking the test piece, at a lesser rate. This distance registered in foot-pounds is shown on a dial above the machine by a pointer moved by the pendulum.

270. What is the Size of the Test Piece used in the Impact Test?

Usually a round bar 5·2 in. long, ·45 in. dia. is used, which has three notches commencing from one end 1·1 in. apart. The notches are milled 45°, depth ·13 in. The test piece is held in the vice so that the centre of the first notch is level with the top of the vice. The mean of three tests is taken for the impact value.

271. Explain the Tensile Test.

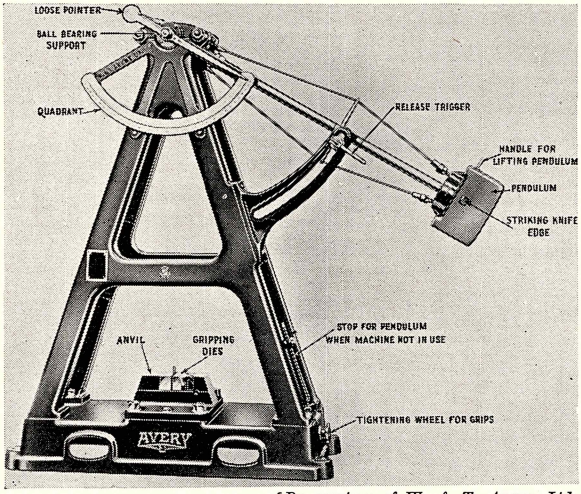
In the small hand-operated type the load is applied by a handwheel which moves a weight along a beam. The load at any time during the test can be read from a scale attached to the beam. The large type machines are either operated by electrical or hydraulic power.

272. Explain the Close Bend Test.

It consists of turning over the corner of the sheet and closing down on to a piece of the same gauge. No crack or fracture must occur at the bend of the material.

273. Explain the Reverse Bend Test.

This consists of holding a prepared piece of sheet metal between blocks, the edges with a radius in accordance with the gauge of the material. Generally the radius is three times the thickness of the material. The projecting end is then bent through 180° for a specified number of times and must stand this treatment without showing any signs of cracking or fracturing.



[*By courtesy of W. & T. Avery, Ltd.*

THE STANDARD "IZOD" IMPACT TESTING MACHINE

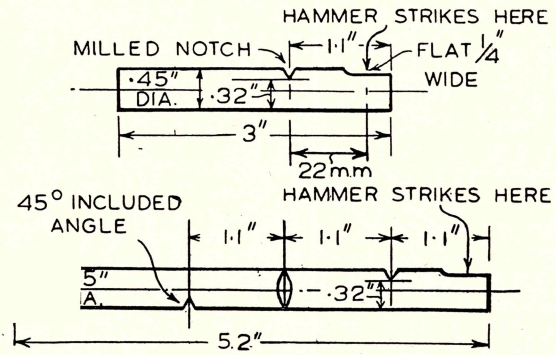


DIAGRAM SHOWING DIMENSIONS OF STANDARD TEST PIECES USED WITH THIS MACHINE

CORROSION AND ANTI-CORROSIVE TREATMENTS

274. Explain the Term "Corrosion."

Corrosion is the disintegration of metal caused by contact with acid, alkalies or electricity.

275. What actually happens when Mild Steel becomes Rusty through Exposure?

This type of corrosion is termed atmospheric corrosion, and attacks the surface, the metal being decomposed as a chemical change takes place, the metal returning to its natural state as a metallic salt. Plating, varnishing or enamelling the metal so as to exclude moisture and oxygen, etc., or adding certain elements to the metal, i.e. chromium to steel, will decrease the possibility of this type of corrosion.

276. What is meant by Inter-Crystalline Corrosion?

This type of corrosion attacks the crystal boundaries, with the result the metal becomes weak and brittle. This type of corrosion can be lessened by adding certain elements to the metal, titanium, tungsten or silicon.

277. Explain Electrolytic Action.

This is corrosion caused by contact of two dissimilar metals, dissimilar in relation to their difference in potential of electricity, the metal with the higher potential (positive) being decomposed. In flying-boat construction stainless steel fittings bolted to duralumin hulls are given a coat of enamel before assembly to lessen the possibility of this type of corrosion.

278. How would Surface Corrosion be Recognized?

On steel—it is a reddish colour (rust).
On aluminium and aluminium alloys—a white powder.

279. What Anti-Corrosive Treatment is applied to Mild Steel Sheet by the Manufacturer?

The treatment is termed the Bowers Barff process. The steel is packed in retorts heated 1,000° F. Steam is then injected for 30 min. and then shut off. A small percentage of naphtha is then injected, steamed 30 min. further, and allowed to cool down to 800° F. The steel is now removed and quenched in oil. The oxygen from the steam combines with the hydrocarbon from the naphtha on the face of the steel and forms a hard glass-like skin.

280. What Precautions should be taken prior to Stove Enamelling?

Ensure that the enamel is approved and the viscosity is as specified. The method of application of the enamel is very important. Discover whether the enamel is for spray, dipping or brushing. The fittings must be cleaned with methylated spirits or another approved cleansing medium and are then dried in warm air.

281. Explain the Stove Enamelling Process.

The fittings having been cleaned, etc., as outlined in the previous answer are, if dipped, allowed to drain for one hour, any blobs or tears of enamel being removed with a brush. They are then usually placed in the stove for $2\frac{1}{2}$ hr. and allowed to cool before removing. (Temperature of stove for steel fittings, 170° C. Light alloy fittings, 125° C).

282. If it were necessary to Stove a Second Coating, would the Time in the Stove be as for the First Coat?

$1\frac{1}{2}$ hr. is usually sufficient.

283. What is most Important when Stove Enamelling ?

The temperature must be even and controlled. Two thermometers are usually used, one near the lower portion of the stove and the other near the upper portion, both being close to the fittings in these regions.

284. What Thinners are added to Enamel ?

The thinners added must be as specified by the maker.

285. Give one Reason why the Temperature must not exceed 170° C. when Stove Enamelling ?

Grade " A " solder melts at 181° C.

286. What Precautions are taken prior to Zinc or Cadmium Coating (Electro-Deposition Process) ?

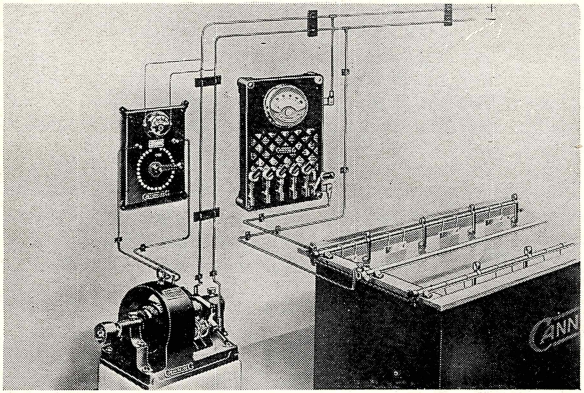
Approval of the plant used, the methods adopted for its operation, the approval of the method adopted to remove brittleness, and the proof of condition by means of physical tests to ensure specification requirements.

287. How are the Parts prepared prior to Plating ?

The parts must be free of grease, rust or foreign matter. The following methods can be adopted : Immersion in a hot caustic bath, sand blasting with fine sand, polishing with emery, or warm solvent vapour treatment.

288. Explain the Cadmium Plating Process.

This process is carried out in a sheet-iron tank, usually containing $1\frac{1}{2}$ to 3 oz. cadmium cyanide and 5 oz. potassium cyanide to a gallon of water. The parts being treated form the cathode and the anode, being cast cadmium plates. The temperature of the bath should be 40° C., the current density 10 amps per square foot of cathode surface, and the pressure from 2 to 5 volts.



[*By courtesy of W. Canning & Co., Ltd.*

CADMIUM PLATING VAT, SHOWING ELECTRICAL CONNECTIONS.

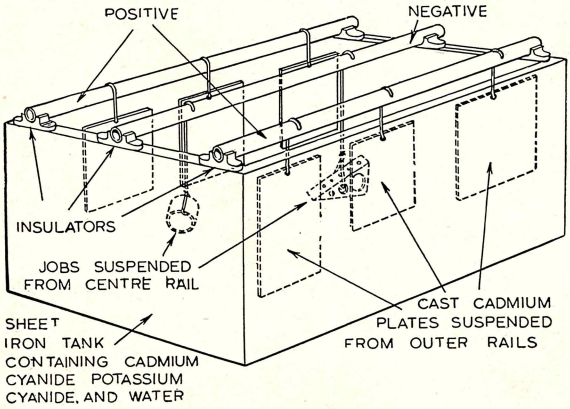

POSITIVE
NEGATIVE
INSULATORS
JOBS SUSPENDED FROM CENTRE RAIL
SHEET IRON TANK CONTAINING CADMIUM CYANIDE POTASSIUM CYANIDE, AND WATER
CAST CADMIUM PLATES SUSPENDED FROM OUTER RAILS

DIAGRAM SHOWING INTERIOR DETAILS OF VAT.

289. Explain Zinc Plating.

Zinc plating is carried out in a similar manner to cadmium plating, the bath containing 12 oz. zinc cyanide, 6 oz. potassium cyanide and 4 oz. caustic soda to a gallon of water, the anode being zinc. The current density should be 2 to 4 amps per square foot of cathode surface, and the pressure from 3 to 5 volts.

290. Why are the Parts, after Treatment, Washed and Heated for 30 min. at 100° to 200° C.?

To remove the plating solution and prevent the occlusion of nascent hydrogen which would induce brittleness.

291. What Test is carried out after Cadmium Plating?

The check bend test. A piece of similar material should be plated with the parts for subsequent testing.

292. Why should the Limits of Changeability be checked after Treatment?

This is essential to ensure that the plating has not interfered with the tolerance laid down, especially with regard to mating dimensions.

293. How is the Thickness of Plating Determined?

The job can be measured before and after treatment. Another method is to weigh a plated part of known weight and area, dissolve the coating from the part in a special solution, then reweigh the part, the thickness of the coating being found by calculation.

294. How Thick should the Cadmium Coating Be?

The thickness of coating should be at least ·0003 in.

295. What Test can be made for Porosity?

The part to be tested must be clean, free from grease, etc. It is immersed in a solution of 1% hydrochloric acid, and the absence of bubbles forming on the surface of the test piece after 10 min. in the solution indicates a satisfactory coating.

296. Explain the Sherardizing Process.

This is a patent process, being a zinc heat treatment used for rust-proofing ferrous metal.

The parts to be treated must be clean, and free from grease or rust. They are placed in a container and packed in with very fine zinc dust. The container is then sealed and placed in the furnace. The container is continuously revolved so that the zinc dust is worked into every face and corner of the parts. The result of this treatment is that the zinc penetrates an appreciable distance into the metal, forming an alloy which is highly resistant to corrosion.

297. What other Patent Anti-Corrosive Treatments can be applied to Ferrous Metals ?

Feezing, platinizing, scarabizing, surf alloy and zinc alloy. (These processes involve the deposition of zinc under heat.) Fescolizing (electro-deposition of nickel). Calorizing (forms a surface alloy of aluminium with the steel). Coslettizing (an iron phosphate coating).

298. What Process is carried out to protect Aluminium and Aluminium Alloys against Corrosion ?

Anodic oxidation.

299. How are the Parts prepared prior to Anodic Treatment ?

The parts must be free from grease, etc., by cleaning with petrol, benzol or solvent naphtha, finally washing with hot water and drying immediately prior to the parts being treated.

300. Explain the Anodic Treatment Process.

The process is carried out in a sheet-iron tank, usually containing 3% chromic acid in distilled water. The bath is provided with a mechanical stirrer to lightly agitate the solution. The parts being treated form the anode and the cathode graphite plates. The temperature of the bath should be 40° C., and the current

density 3 to 4 amps per square foot of surface to be treated. The voltage for the first 15 min. is raised from 0 to 40 volts, maintained for 35 min., then increased from 40 to 50 volts in the next 5 min., and remains at 50 volts for the last 5 min., the entire process occupying one hour. After treatment the parts are washed in hot water, then dried.

301. How can the Quality of the Treatment be Determined ?

By visual examination or, if a cheap dye or indelible pencil is marked on the part, when the treatment is satisfactory it will retain same when rubbed with a damp cloth. This test can only be carried out immediately after treatment.

302. Is Anodic Treatment a Plating ?

This process is not a plating, but the surface of the metal becomes covered with a film of aluminium hydroxide, formed from the metal itself.

303. How are Magnesium Alloys protected against Corrosion ?

By the chromate immersion process.

304. Explain the Chromate Immersion Process.

The parts are cleaned in diluted nitric acid and then gently boiled for 6 hr. in a solution containing potassium bichromate, potassium alum and caustic soda. After treatment the parts are thoroughly washed in hot water, dried and examined. If local yellowish stains are present the parts must be rewashed until clear, otherwise blistering will take place when the parts are subsequently enamelled. In appearance the parts will be of a yellow to a purple colour after treatment.

WELDING

305. Name the Two Common Methods of Welding.

Oxy-acetylene and electrical.

306. What is Acetylene?

Acetylene is a gas produced by the action of water on calcium carbide.

307. How can the Difference between Oxygen and Acetylene Cylinders be Determined?

Acetylene cylinders and regulators are painted red and fitted with left-handed threads. Oxygen cylinders are painted black and are fitted with right-handed threads.

308. Explain the Construction of an Acetylene Cylinder.

The cylinder is filled with a porous material such as fossil meal, saturated with a liquid hydro-carbon known as "Acetone" which is capable of absorbing 25 times its own volume of acetylene for every atmosphere of pressure. The quantity of acetone is regulated to give an acetylene content of 10 volumes for every atmosphere of pressure. The cylinders are usually compressed at 10 atmospheres, i.e. 150 lb. per square inch approx.

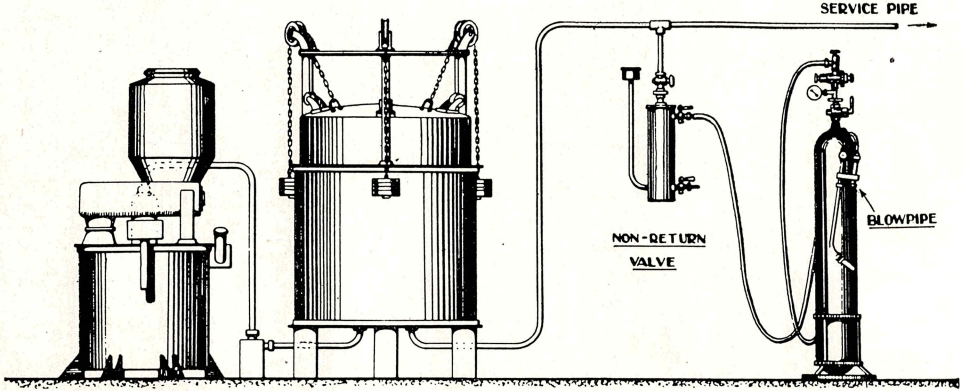
309. What are the Advantages of the High Pressure System?

This system requires no generating apparatus, piping or hydraulic valve. There is no sediment and the gas is pure.

310. What Method is used to Check the Purity of the Acetylene?

A piece of white blotting-paper is soaked in 10% solution of silver nitrate and has the gas blown on to it. If it discolours the blotting-paper then the gas is impure.

LOW PRESSURE ACETYLENE WELDING PLANT



311. How Often must the Gas be Tested for Purity?

Every day if gas generators are used.

312. What are "Herotol" and "Frankolin"?

Purifying materials, used in the purifier in conjunction with the gas generator. They consist of porous earth which has absorbed certain acids. The gas passes through this material and the chemical action taking place removes the impurities, sulphur and phosphorus being two well-known impurities having a detrimental effect in a weld.

313. What Precautions must be taken when Using these Materials?

Owing to the acid, corrosion will occur when in contact with metallic materials. The purifier, if of iron or steel, must be protected before the materials are used.

314. If the Plant had a low Pressure System, what would be the First Thing to Look For?

An hydraulic safety valve must be fitted between the acetylene holder and the blowpipe for the purpose of eliminating the possibility of oxygen entering the acetylene piping should the nozzle fuse or any other obstruction occur.

315. What is the Best Flame for Ordinary Welding Operations?

It is termed a neutral flame, and is obtained when the blue cone nearest to the jet carries a slight fringe or feather of white flame.

316. What is a "Carbonizing" Flame?

A long brilliant flame due to excess acetylene. This type of flame will discolour and tend to carbonize the weld, and thus harden the welding seam with the result that the weld will be weak.

317. What is an "Oxidizing" Flame?

A short and pale flame due to excess oxygen. Owing to the free oxygen the metal burns, which is very injurious to the metal.

318. What is the Approximate Temperature of the Oxy-Acetylene Flame?

3,320° C.

319. Prior to Welding how should the Parts to be Joined be Prepared?

The edges and surfaces of the parts to be welded should be thoroughly cleaned by means of a file, wire brush or emery cloth so that the surfaces are free of oxide, oil or grease. If a repair is to be made, i.e. to the fuselage or rudder, the parts must be fitted in a jig to prevent distortion. Bevelling need not be carried out with metal under $\frac{1}{8}$ in. thick. Metal $\frac{1}{8}$ to $\frac{1}{4}$ in. thick should be bevelled 25° so that the "V" is 50°. Metal $\frac{1}{4}$ to $\frac{3}{8}$ in. thick should be bevelled 45° so that the "V" is 90°. Metal $\frac{3}{8}$ in. thick and upwards should be bevelled 45° both sides of the metal and welding carried out on both sides of the joint.

320. What are the Faults to be found in Bad Welding other than those Caused by an Incorrect Flame?

Lack of penetration, adhesion, burning and channelling.

321. What is Lack of Penetration?

This is due to there being too great a thickness of metal at the base of the weld, incorrect bevelling or to hurrying over the operation of fusing the base of the "V." It can be detected by examining the underside of the weld, both edges being in an unfused condition.

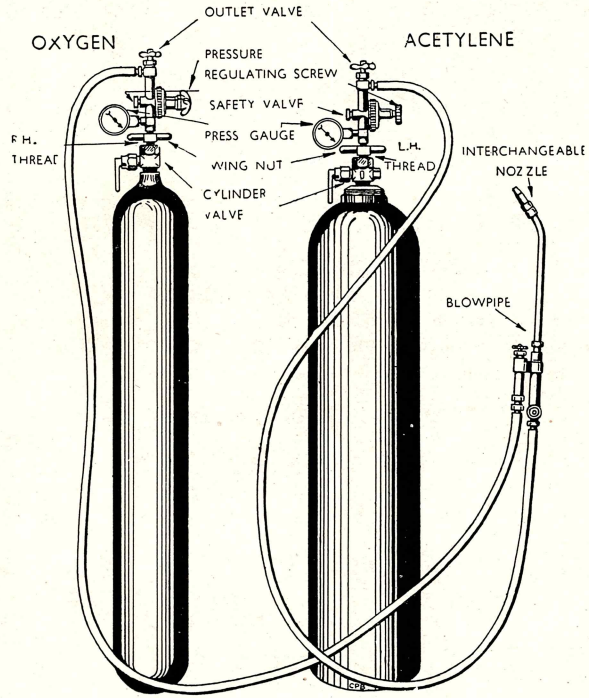


FIG. 1.—CYLINDER EQUIPMENT AND BLOWPIPE USED FOR HIGH PRESSURE WELDING

322. What is Adhesion?

This is said to exist when the added metal adheres without fusion to the sides of the weld, due to the molten metal flowing prior to bringing the edges of the material to a state of fusion.

323. Explain Burning.

The surface of the burnt portion becomes heavily oxidized and may become covered with metal from the welding rod, which will adhere without fusion. This is generally caused by the use of too small a blow-pipe, which is unable, without undue application to one spot, to raise the temperature of the metal to fusion point.

324. Explain Channelling.

This consists of a groove or trough below the surface of the work on each side of the added metal, caused through insufficient metal being added from the welding rod.

325. Is the Piping from Cylinder to Blowpipe of Copper?

Under no conditions must copper pipes be used, as the acetylene in contact with copper is liable to form acetylide of copper, which is an explosive compound.

326. Why should the Job, whenever possible, be Pre-Heated?

To lessen the possibility of cracking due to internal stresses.

327. What Further Treatment is Applied to Mild Steel Fittings after Welding?

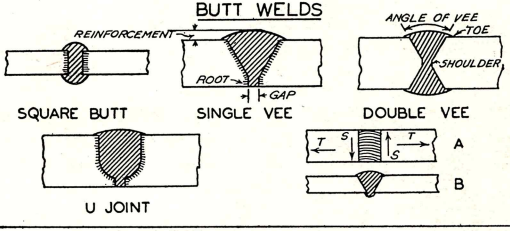
They are normalized to relieve internal stresses, refine the crystalline structure, etc.

328. When is Flux Used?

When welding cast iron, aluminium, aluminium alloys, copper and brass only.

TYPES OF WELDS

BUTT WELDS



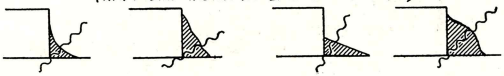
SQUARE BUTT | SINGLE VEE | DOUBLE VEE

U JOINT

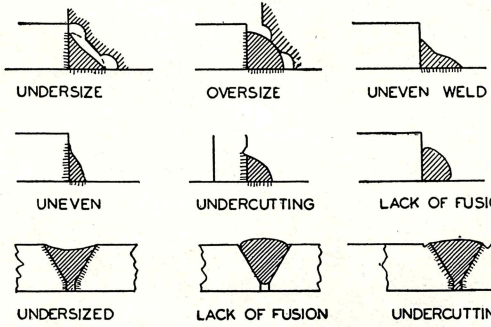
FILLET WELDS

FAILURE OF FILLET WELDS

(WAVY LINE INDICATES LINE OF FRACTURE)



FAULTS IN WELDS



UNDERSIZE | OVERSIZE | UNEVEN WELD

UNEVEN | UNDERCUTTING | LACK OF FUSION

UNDERSIZED | LACK OF FUSION | UNDERCUTTING

329. Why is Flux Used?

1. It prevents the formation of oxide on the surface of the metal.
2. It increases the fluidity of the molten metal.
3. When soldering it assists the adhesion between solder and metal.

330. Why are Aluminium Parts Washed in Boiling Water after being Welded?

So that all trace of the flux is removed, otherwise corrosion will occur.

331. State an Essential Requirement of Flux?

It must be free from mineral acid. Liquid flux can be tested by dipping methyl-orange paper into the flux after it has been diluted with an equal volume of water. Should the paper turn pink, the presence of mineral acid is indicated.

332. If Welding Iron or Steel What Kind of Welding Rod should be Used?

Soft iron. The welding rod is generally of the same composition as the parts being welded.

333. Detail the Inspection of a Welded Fitting.

Ensure that approved materials have been used and that the material added from the welding rod forms a fillet of regular size. Ensure that satisfactory fusion has been obtained, that the fusion zone is free from cracks, porosity and burning, and also that the material is not reduced in thickness. All welds must be left in the " as welded " state, no attempt having been made to file, grind or machine before inspection.

FABRIC AND DOPE

334. What Type of Fabric is Used on Aircraft?

Irish linen, which is made from yarn manufactured from flax fibre.

335. What is the Weight of Fabric?

It should not exceed 4 oz. per square yard.

336. How is the Fabric Inspected for Defects?

By passing the fabric yard by yard over an artificial light table.

337. What Type of Machine is Used to Test the Tensile Strength of Fabric?

Usually the Avery fabric-testing machine.

338. What is the Width of Aircraft Fabric?

54 in. or 38 in. from selvedge to selvedge. 54 in. is generally used to cover the fuselage.

339. Explain the Selvedge, Warp and Weft?

Selvedge—Is the edge of the fabric running parallel to the warp, and is woven in such a manner to prevent unravelling.

Warp—Is the threads running lengthwise and parallel to the selvedge. These threads are named ends.

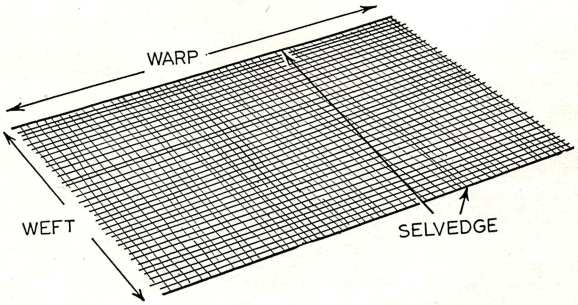
Weft—These threads run across the warp and are named picks.

340. What Type of Thread is Used when Sewing?

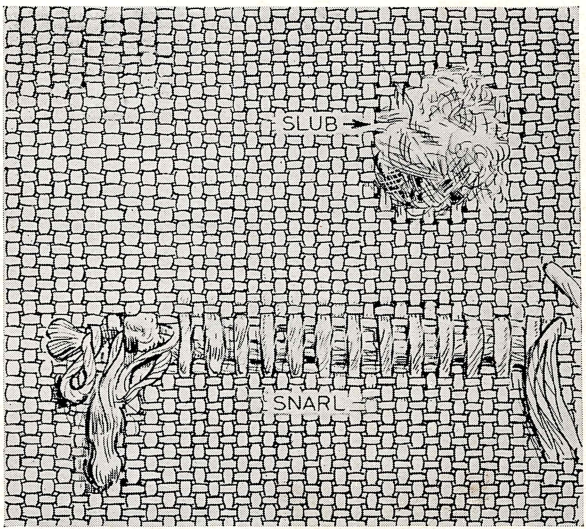
If linen fabric is being sewn then linen thread must be used. Single 18S or double 40S thread should be used.

341. Name a few Defects to be Found in Fabric.

Snarls (entanglements). Slubs (twists). Oil, rust marks or knots.



FABRIC TERMS



DEFECTS FOUND IN FABRIC

342. If a Small Piece of Red Thread is Attached to the Selvedge, what will this Denote?

That opposite the red thread will be found a serious defect in the fabric.

343. The usual Length of a Piece or Web of Fabric is 100 yd., how many Defects are Allowed in One Piece?

These marked faults must not exceed six, and must be cut out prior to the use of the fabric.

344. When Testing Fabric how many Test Pieces are Used?

Six. Three are tested for strength in the direction of the warp, and three in the direction of the weft.

345. What must the Test Reports Show?

The Authority Reference Number of approval. The serial number of the web. The source of manufacture. Date and weight of the fabric per square yard. A count of the ends and picks per inch. The respective mean strength values of the six test pieces.

346. How many Ends and Picks to the Inch should Fabric Contain?

It should not contain less than 80 ends and not less than 90 picks to the inch.

347. At what Temperature should Fabric be Stored?

The temperature should be fairly high, 72° F. Any moisture present would then evaporate. Moisture prevents satisfactory doping.

348. Why when Testing Fabric for Strength is it Tested Wet?

The object of wet testing is to ensure that testing conditions are uniform as the humidity affects the strength of linen fabric. The strength is greater wet than dry. The strength of fabric tested wet, must be 90 lb. (min.) per inch of warp or weft.

349. If Fabric had to be Attached to Plywood and subsequently Doped would Glue be Used to Attach the Fabric ?

No, dope is usually used as the adhesive. Glue will affect the dope and give a poor finish. When the fabric is subsequently painted, glue is then used to attach the fabric to the plywood.

350. What Type of Stitch is Used along the Trailing Edge ?

The hand-locking stitch. Seven stitches approx. are spaced to the inch, double-lock stitched every 6 in.

351. How is the Fabric Attached to the Ribs ?

By stringing. The standard type of stringing in use is done by passing cord-braided string through the top and bottom surfaces of the fabric at intervals of 3 in., secured on the top surface by a non-slipping knot. If the horse-power of the engine exceeds 400 the stitching is reduced in the slipstream area to $1\frac{1}{2}$-in. interval. Stringing is double-knotted every 18 in.

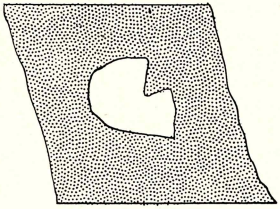
352. What Purpose does the Doping Scheme Serve ?

Dope is used because it imparts tautness. It provides an even and continuous surface and offers the minimum resistance to the airflow. It also renders the fabric, oil, water and petrol proof and protects the fabric from the effects of light. Finally, it adds considerably to the strength of the material and prevents deterioration.

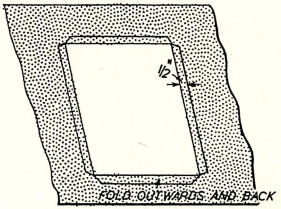
353. What is the Procedure for Repairing a Jagged Tear in the Fabric ?

Cut the damaged area in the form of a square, cut the corners and fold backwards $\frac{1}{2}$ in. Then cut a piece of fabric 3 in. larger than the square and fray the edges $\frac{1}{4}$ in. all round. Baste in position and sew to the $\frac{1}{2}$ in. upward folded edges, using either the chain or boot stitch (5 stitches to the inch). The folded $\frac{1}{2}$ in. lap of

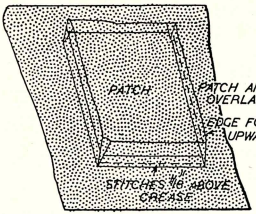
FABRIC REPAIRS



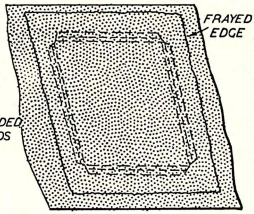
TEAR IN FABRIC



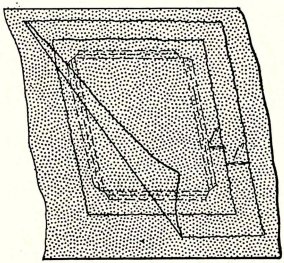
RECTANGLE CUT OUT



PATCH IN POSITION READY FOR STITCHING



OVERLAP AND INSERTION PATCH DOPED DOWN



LARGE PATCH STUCK OVER

the cover is doped down first, then the 1½ in. overlap of the patch. When dry the whole of the patch is doped. A piece of fabric 1 in. larger all the way round than the patch is then doped over the repair.

354. What is meant by " Basting " ?

Temporarily stitching.

355. Why is the Ladder Stitch Used to Repair a Cut in the Fabric ?

The ladder stitch gives even and equal tension to both edges of the cut. The repair is very strong though flat. There should be four stitches to the inch.

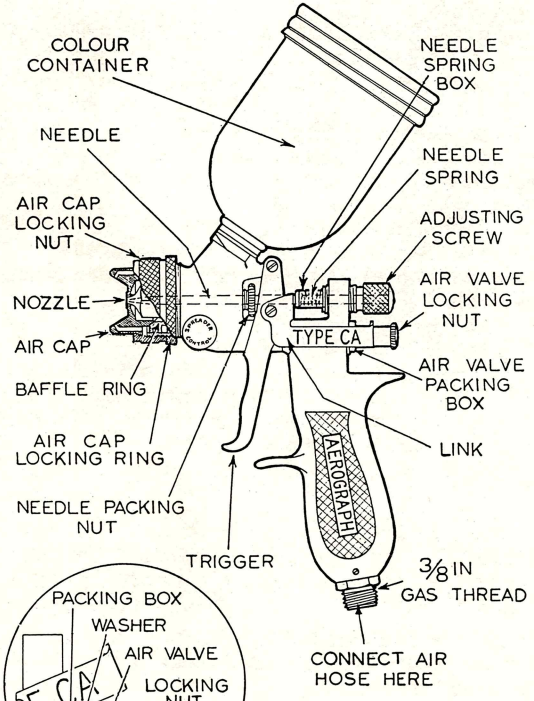
356. What Happens to Dope if Applied in a Draught ?

The dope has a very bad finish, the dope " blushing," i.e. whitish streaks appear.

357. Under what Conditions should Doping be Carried Out.

The component being doped must be situated between the heating apparatus and the fans, which should change the air 24 times in the hour without causing any draughts. The ordinary dopes should be applied in a room free from draughts, with a temperature not below 68° F. ; the humidity should not exceed 50%. The first coat of dope while wet is generally rubbed down with a piece of fabric to ensure penetration ; the pressure must be such that the rubbing down will not strain the fabric. Subsequent coats of dope can be applied with the spray gun, care being taken to ensure an even and continuous coating. Two coats of dope and one of aluminium varnish are usually applied for day-flying aircraft, but the number of coats varies with different doping schemes. The anti-chill dope can be used under adverse conditions, the temperature being as low as 32° F., and humidity 90%. There should be no draughts.

A TYPICAL SPRAY GUN



By courtesy of the Aerograph Co., Ltd.

INSTRUMENTS

358. What Precautions are Taken when Installing the Compass?

The bowl must be inspected for dents or damage. It must be filled with the specified liquid and free from bubbles. The pivot must be free from friction, also the card, bowl, liquid and window must be free from discoloration. No part of the aircraft must be in contact with the compass. The bolts and support must be non-ferrous and any ferrous metal near to the compass must not introduce errors in the readings. The word " aft " on the compass must be noticed and the lubber line checked for being parallel or coincident with the centre line of the machine. When the machine is in flying position the magnet system must be in a normal untilted position. If a corrector box is fitted separately, its centre must be immediately below the centre of the compass with the magnet holes exactly fore and aft and athwartships respectively.

359. How should the Compass be Tested for Pivot Friction?

By means of a corrector magnet deflect the magnet system about 5°, remove the magnet, and let the magnet system come to rest. If it settles down to its original position, the compass is free from pivot friction.

360. If the Magnet System did not Return to its Original Position is the Compass Unserviceable?

Not if the tapping of the bowl with the finger (equivalent to the vibration of the machine) positions the magnet system.

361. What Liquid is in the Bowl?

Generally alcohol and distilled water.

362. If there was a Bubble in the Bowl, how would this Affect the Compass ?

A disturbance named " liquid swirl " would be set up, which causes the magnet system to oscillate.

363. What Causes Discoloration ?

Discoloration is caused by the action of the alcohol on the metal or painted parts inside the compass.

364. How is the Compass Bolted to the Aircraft ?

Duralumin or brass nuts and bolts are used.

365. What Methods are Adopted to Damp out Vibration ?

The magnet system is damped by the liquid in the bowl. The compass is generally floating on springs assisted by felt pads or sorbo-rubber.

366. Why is an Expansion Chamber Fitted ?

To allow for the change in volume of the liquid at different temperatures and heights.

367. What are the Cardinal and Quadrantal Points ?

N., E., S., W. and NE., SE., SW., NW. respectively.

368. What is Meant by Deviation ?

Deviation denotes the error in the compass reading, due to internal influences in the aircraft.

369. How is the Deviation Rectified ?

By placing small magnets in the corrector box until the true reading is obtained.

370. Explain the Co-Efficients.

Co-efficients are the corrections and referred to as " A," " B," " C," " D," and " E."

371. In what Order are the Co-efficients Obtained ?

" C," then " B," then " A " if it exists.

372. Explain the Co-Efficient " C."

Co-efficient " C " is the influence of an imaginary magnet lying athwartships in the aircraft and therefore affecting the magnetic north and south.

373. Explain the Co-efficient " B."

Co-efficient " B " is the influence of an imaginary magnet lying in the fore and aft line of the aircraft and therefore affecting the magnetic east and west.

374. Explain the Co-efficient " A."

Co-efficient " A " is a disturbing effect which is the same on all bearings due to incorrect setting of the lubber line or incorrect mounting of the card upon the magnet system and sometimes due to the distribution of soft iron in the aircraft.

375. How is Co-efficient " C " Calculated ?

By noting the deviations at north and south (having changed the sign of that south), subtracting one from the other, and dividing by two. If the answer is plus, corrector magnets should be placed in the corrector box, red ends to starboard ; if minus, blue ends to starboard. The number of magnets is governed by the degree of deviation.

376. How is Co-efficient " B " Calculated ?

By noting the deviations at east and west (having changed the sign of that west), subtracting one from the other, and dividing by two. If the answer is plus, corrector magnets should be placed in the corrector box, red ends forward ; if minus, blue ends forward. The number of magnets is governed by the degree of deviation.

377. How is Co-efficient "A" Calculated and Corrected For?

By taking the mean deviation on the eight cardinal and quadrantal points, and then rotating the compass the requisite number of degrees. If a plus, the compass is rotated clockwise and if minus, anti-clockwise.

378. If Co-efficient "A" exists, how will this Affect the Final Readings on the Deviation Card?

The final readings on the deviation card will be plus or minus a number of degrees to those previously noted when swinging the compass through the eight points.

379. When Correction is made for Co-efficient "A," the Position of the Lubber Line is Altered. What should be done about This?

Check the lubber line for being parallel or coincident with the centre line of the machine.

380. Can Co-efficients "D" and "E" Deviations be Corrected?

Not on an aircraft compass. These deviations are due entirely to soft iron magnetism affecting cardinal and quadrantal bearings.

381. What Precautions are taken before Swinging the Compass?

The compass base must be at least 50 yd. from any building or object likely to affect the compass. The person swinging the compass should not have any magnetic material about him—i.e. tools, keys, etc. Ensure that the corrector box is empty of magnets, and that the tyres are evenly inflated. All the machine's flying equipment should be in position and the attitude of the aircraft should be the normal flying position.

382. What is the Procedure for Swinging the Compass ?

Place the aircraft heading north and note the deviation. Then place the aircraft heading east and note the deviation. Then place the aircraft heading south and note the deviation. Calculate co-efficient " C " and correct for it. Next place the aircraft heading west and note the deviation. Having already noted the deviation on east calculate co-efficient " B " and correct for it. Next swing the aircraft through the eight cardinal and quadrantal points in turn, and note the deviations. If co-efficient " A " exists, correct as directed in answer 377.

383. Having adjusted the Compass is there anything further to be attended to ?

Ensure that the corrector box cover is secure. Enter particulars of magnets used in the log book. Fill in completely a deviation card and mount near the compass.

384. For what Purpose is the Air-speed Indicator Fitted ?

The air-speed indicator shows the speed at which the aircraft is travelling relative to the air, and not the speed of the aircraft passing a point on the ground.

385. Explain the Principle of the Air-speed Indicator.

The instrument consists of an airtight case, in which an elastic metal box, generally made of nickel silver, is mounted in a frame. The elastic metal box is connected to the pressure tube from the pressure head, the static tube from the pressure head being connected to the airtight case. The pressure of the air expands the elastic metal box and by means of a crank actuates a quadrant which moves the pointer. A reading is thus given upon the dial. The dial is marked in m.p.h. or knots.

386. Why is the Static Tube connected to the Case?

The reading on the dial shows the difference between the pressure in the pressure tube and the pressure of the still air in the static tube.

387. What is the Pressure Head (Pitot Head) and where is it Fitted?

The pressure head consists of a pressure and static tube parallel to one another, fitted with the aircraft in flying position, the head being exposed to the wind pressure, and parallel to the datum line. It is fitted two-thirds of the way up the front outer interplane strut, or in such a position that it will be clear of the slipstream.

388. The Connecting Tube from Pressure Head to Instrument is generally of Aluminium. What Type of Tubing is used in Seaplanes?

Copper (cadmium coated).

389. What Type of Joint is Used?

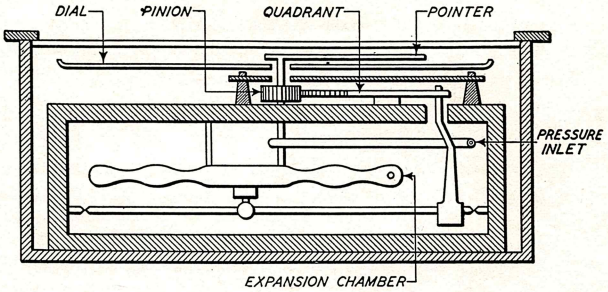
Generally the joint is made by the ends of the tubing entering an adaptor made of duralumin. The joint is made airtight by nuts, screwed to the adaptor, compressing a rubber ring to the tube. (The adaptor and nuts are made from brass for seaplanes.)

390. How should the System be Tested for Leaks?

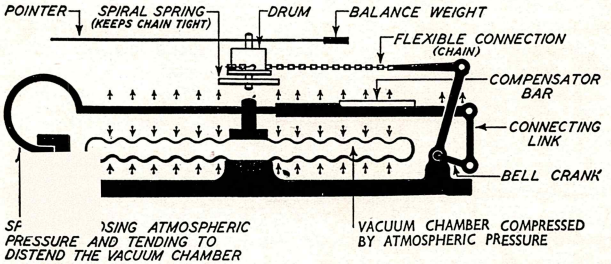
Attach a short piece of rubber tubing to the pressure tube and roll up the rubber tubing to create a pressure until the reading is, say, 120 m.p.h., then pinch the tube. If there is a leak the pointer will return to zero. The static tube can be tested in the same way, except that the rubber tubing is squeezed to expel the air from the tube.

391. Explain the Construction of the Pressure Head.

It consists of pressure and static tubes, the open end of the pressure tube being exposed to the wind pressure,



SECTIONAL DIAGRAM OF AN AIRSPEED INDICATOR SHOWING COMPONENT PARTS AND DETAILS OF CONSTRUCTION



SECTIONAL DIAGRAM OF AN ALTIMETER SHOWING COMPONENT PARTS AND DETAILS OF CONSTRUCTION

while the static tube is sealed at the end facing the wind pressure, but is pierced with a number of small holes a short distance from the end.

392. How is the Instrument checked for Accuracy ?

By means of a manometer. The instrument should be accurate $\pm$ 3 m.p.h.

393. Why is the Cross Level Fitted ?

To indicate the attitude of the aircraft relative to the horizontal.

394. Describe a Cross Level.

A cross level is a curved glass tube mounted in a frame, the tube being partially filled with a non-freezing liquid enclosing a bubble. This instrument is fitted when the machine is in flying position, with the bubble in the centre of the tube.

395. For what Purpose other than Answer 393 is a Cross-level Fitted ?

It serves as a banking indicator, informing the pilot whether he has over or under banked. Owing to centrifugal forces the bubble remains central if the degree of bank is correct.

396. What Precaution is taken against the Liquid bursting the Tube at High Temperatures ?

An expansion bulb is fitted to the end of the glass tube.

397. How can the Size of Bubble be Decreased or Increased ?

By shaking the liquid to or from the expansion bulb.

398. What is the Approximate Length of the Bubble ?

Half an inch.

399. Why is the Fore and Aft Level Fitted?

The name of the instrument explains itself. It denotes the fore and aft inclination of the longitudinal axis of the aircraft to the horizontal.

400. How should the Fore and Aft Level be fitted to the Aircraft?

Place the machine in flying position. The instrument is then fitted so that the side marked in degrees is vertical, the level of the liquid being at 0°.

401. Describe the Fore and Aft Level.

The level consists of a glass tube shaped to form a triangle, partially filled with a non-freezing liquid which is generally coloured black. Only one side of the glass tube is visible. When the aircraft is in normal level flight the level of the liquid is in the centre of the tube, i.e. at 0°. While the aircraft climbs, the liquid rises in the tube and falls while the aircraft descends.

402. Why is the Altimeter Fitted?

It indicates to the pilot the height of the aircraft above the aerodrome.

403. What is the Principle of the Altimeter?

This instrument measures the pressure exerted by the atmosphere, which decreases with altitude. The dial of the instrument gives the height in feet, the decreased pressure at any specific height having been found by calculation. The instrument consists of the case, which is not airtight, inside which is an elastic metal box exhausted of air. One side of this is fixed to a base plate and the other side to a leaf spring. Owing to the change in pressure the metal box expands or contracts, moving the leaf spring, which moves a straight lever connected to a bell crank lever. This in turn, by means of a chain, arbor and spindle moves the pointer. In modern cabin type aircraft, the altimeter is connected to the static tube of the air-speed indicator to ensure that the density of the air is correct.

404. State a Rough Check for Accuracy of Instrument.

If the altimeter under test is placed in a chamber together with another instrument known to be accurate and the air gradually exhausted, the readings of both instruments should correspond.

405. How is the Altimeter compensated for Temperature Variation?

A compensating bar, generally of steel, is fitted to the brass straight lever. The two metals have not the same rate of expansion, and so the effective length of the lever remains unaltered.

406. Why is a Hair Spring Fitted?

To take up backlash, and also to keep the chain taut.

407. How should an Altimeter be fitted to the Aircraft?

Place the aircraft in flying position. The instrument should be fitted with the face vertical and the adjusting knob at the bottom of the instrument.

408. Why is the Turn Indicator Fitted?

This instrument assists the pilot to maintain a straight course and gives him a clear indication of departure from normal flight when the horizon is obscured or the ground not visible.

409. Explain the Principle of the Turn Indicator?

The instrument consists of a small gyroscope mounted in a frame named a gimbal ring. It is well known that a gyroscope revolving at a high speed will tend to preserve its direction in space. The gyro is either driven by air or electricity. The axis of the gyro is in a transverse direction and the axis of the gimbal ring is fore and aft. When the aircraft turns the gyro maintains its direction but the gimbal ring to which is attached the pointer turns, the rate of turn being read on the dial.

410. How should a Turn Indicator be Fitted?

The instrument should be installed as stated in the instructions issued with the instrument. Generally it is fitted with the aircraft in flying position, the dial of the instrument being vertical and the pointer central.

411. Where is the Venturi Tube Fitted?

Generally on a strut in the slipstream, with the arrow on the Venturi pointing forward.

412. Describe the Venturi.

The Venturi is a tapered tube ; the flow of air through the tube passing an aperture at its narrowest point, causes a reduction of pressure. The tube from the aperture is connected to the instrument, and the reduction of pressure creating a suction draws air from the instrument through a jet. This air from the jet strikes the grooved periphery of the gyro wheel which rotates at a very high speed.

413. What Adjustments can be carried out on the Turn Indicator?

The sensitivity of the instrument can be adjusted by the tension of a spiral spring. This spring is controlled by a screw set in the side of the instrument. The gauze which filters the air before entering the jet must be cleaned frequently. The gauze can be removed if the three screws securing the filter cap at the back of the instrument are removed. It is very important that the Venturi be kept free from oil and dirt.

414. If any of these Instruments were defective who is permitted to repair Same?

Ground engineers licensed " A " or " B "category are not permitted to repair aircraft instruments. All instruments when defective must be returned to the makers.

PETROL, OIL AND WATER TANKS (STEEL, BRASS OR COPPER)

415. What is the Inspection Procedure for New Tanks?

Ensure that the materials, fittings and parts used are in accordance with drawings and specifications. The workmanship and cleanliness of the interior is very important. All soldered details must have splashes, blobs or feathers of solder removed, and must then be washed in hot water to remove any trace of flux.

416. Should Tanks be Tested for Weight?

Yes. The finished tanks should be weighed to ascertain that they conform to the limits of weight specified.

417. Should Tanks be Tested for Capacity?

The first tank of any batch must be tested for capacity by filling with paraffin and the whole quantity measured by draining into a calibrated vessel. Limits of capacity of tanks constructed to hold 10 gal. or more are $\pm$ 2% of the specified capacity. Tanks of lower capacity than 10 gal. must not have a capacity less than $-$ 2% of the specified capacity.

418. What Pressure Test is Applied to Tanks?

The seams and fittings of tanks should be covered with whitening, and a quantity of paraffin, at least 10% of the specified capacity of the tank, should be poured in. All openings being sealed, an internal pressure of air should be applied of $1\frac{1}{2}$ lb. per square inch. The pressure must be held for 20 min. without loss.

419. State an Important Requirement of Oil Tanks.

They must be provided with an air space which varies according to the size and type of engine used in the aircraft. The filler cap must be marked with the correct capacity represented after air space has been deducted.

420. How are Petrol Cocks and Valves Tested?

These accessories, unless otherwise stated, are subjected to an internal pressure of 15 lb. per square inch, the cocks or valves being totally immersed in paraffin. For the flow test, petrol must be used. The test is carried out to ensure that the flow of petrol in gallons per hour will not be less than the minimum called for on the drawings or specifications.

421. How are Oil Coolers Tested?

They are generally subjected to an internal pressure of 25 lb. per square inch with mineral oil (temperature, 40° C. min.). By coupling up the inlet pipe of the cooler to a tank of oil at 40° min., and allowing the oil to flow freely through the cooler, observations can be made to ensure that each element warms up in its turn and at the same time the interior will be cleansed. With the cooler filled with hot oil an internal pressure of 25 lb. per square inch should be applied for a period of 15 min. without any leakage. The relief valve is tested to 15 lb. per square inch, when it should open.

422. How should Radiators be Tested?

They should be checked for weight and capacity. The hot-water test should also be applied as follows: The radiator is completely filled with hot water (180° F. min.), and must withstand a pressure of 6 lb. per square inch for a period of 10 min.

423. Outline the Cold Water Test.

After being tested as above, the radiator is immediately emptied of the hot water and filled with cold water.

It is then subjected to a pressure test of 6 lb. per square inch for 30 min., during which no evidence of leakage must occur.

424. Describe the Flow Test.

This test is carried out with a head of water (7 ft. max.) measured from the surface of water in the supply tank to the radiator inlet level. The water being discharged must issue from the radiator outlet without restriction. If it is found necessary to employ a branch pipe, its outlet must be below 12 in. of the radiator outlet. A calibrated vessel is used to collect the water discharged during the timed period (not less than 20 sec.).

425. How Many Inspection Stamps are to be Found on Radiators?

On new radiators—two. One on completion of the process inspection, and the second on completion of tests. On a repaired radiator, two further stamps are applied, one for inspection and retesting of the radiator and the other for the letter " R." All these stamps are impressed on blobs of solder on the radiator casing close to the filler neck.

GENERAL QUERIES

426. What is Meant by the Term "Swarf"?

Swarf is the cuttings from drill, reamer or file.

427. What Effect will Too Much Stagger Have upon a Machine?

It will induce a tendency to fly tail-heavy.

428. Why are Tubes Cold Drawn?

Cold working improves the tensile quality without impairing the other qualities.

429. What is Lanoline?—From What is it Obtained—Is it of any Use for Marine Aircraft Maintenance?

It is an animal fat, obtained by compressing sheep's wool, used as an anti-corrosive treatment on hulls and floats. It will not wash off when the aircraft is taxying.

430. What is the Weight of a Gallon of Petrol?

Aviation petrol weighs 7·7 lb. approx. per gallon.

431. How Often will the Certificate of Airworthiness have to be Renewed?

Annually, unless otherwise stated.

432. What is Meant by "Service Bolting"?

Temporarily bolting before riveting. This prevents the metal creeping when carrying out this latter operation.

433. What is the Object of Aileron Droop?

If droop is given to the ailerons, slackness in the control cables will be taken up when the controls are in use.

434. When Filled, How Long do the Log Books have to be Retained?

For 2 years after the last entry.

435. How may a Stainless Steel, Mild Steel or High Tensile Steel Bolt be Recognized?

If of Stainless Steel, the bolt has a groove round the head and is generally marked with the letters "S.S."

If of Mild Steel, the bolt has a plain unmarked head.

If of High Tensile Steel, the bolt has a groove round the head.

436. When Inspecting Cable prior to Splicing, What Procedure is Followed?

See that the cable is as specified, with no missing wires, and that it is not kinked, or the wires or strands slack, crossed, etc.

437. How Long do the Daily Certificates have to be Retained?

For 6 months.

438. What is the Method of Increasing the Incidence of a Wire Braced Biplane?

Slacken the rear-landing and long-incidence wire one turn, then tighten the rear-flying and short-incidence wire one turn. (The answer to this query is governed by the type of aircraft, though this answer will apply in certain cases.)

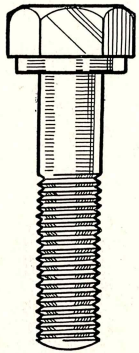
439. Having Fitted a new Streamline Wire, Explain the Inspection of Same?

Ensure that the correct size wire has been fitted, and that it is not damaged. Test for tension, safety, butting, streamline and locking.

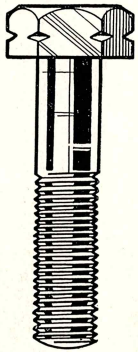
440. Explain the Term "Rigging Position"?

It is the correct attitude of the fuselage for the assembly and truing up of the component parts.

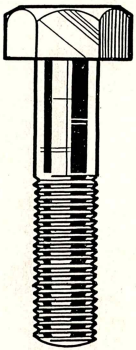
IDENTIFICATION OF BOLTS



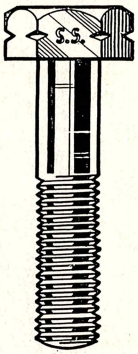
DURALUMIN



HIGH TENSILE STEEL



MILD STEEL



HIGH TENSILE STAINLESS STEEL

441. Why is Tape Placed along the Ribs after Covering the Plane with Fabric?

It is used to reinforce the fabric against tearing when stringing.

442. Explain the Term "Tempering"?

It means heating a steel to a temperature below the carbon change point with the object of reducing the hardness or increasing the toughness to a greater or lesser degree.

443. How Often will the Certificate of Registration have to be Renewed?

Whenever the ownership of the aircraft changes hands.

444. How may an Aluminium snap head Rivet be Recognized?

Aluminium snap head rivets have a centre pop in the maker's head.

445. Why is Elektron Used in Aircraft Construction?

Elektron has a very high strength-for-weight ratio.

446. State a Means of Ascertaining the Correct Drill Size to Use when Tapping a Hole (Practical Method).

Measure the small end of the taper tap. For B.S.F. threads a fractional drill a size larger than the one that will enter the nut will be found suitable when tapping a hole in mild steel.

447. What is Meant by a "Type" or a "Subsequent" Aircraft?

The first machine to be built to a certain design is referred to as a "Type" aircraft. "Subsequent" aircraft are those built to the same design as the "Type."

448. Should Fibre Fairleads be Lubricated?

If this were done, the lubricant would collect dirt and grit and tend to wear the cable. If the fairleads are a snug fit round the cable, swelling of the fairleads may occur and cause undue friction and wear to the cable. Thus fibre fairleads should never be lubricated.

449. Having Completed the Splices of a New Control Cable what Load is Applied before Fitting the Cable into the Aircraft?

The cable is stretched by the application of a load equal to 50% of the breaking strain of the cable.

450. Explain the Terms "Limit," "Tolerance," and "Allowance."

Limit—extreme size high or low. Tolerance—difference between high and low limits. Allowance—difference in dimensions to allow for various fits.

451. Explain the Terms "Wash-in" and "Wash-out."

Wash-in denotes that the incidence of the mainplanes is increased towards the wing-tips.

Wash-out denotes that the incidence of the mainplanes is decreased towards the wing-tips.

452. Why have Certain Aircraft a Wash-in?

To counteract the effect of airscrew torque.

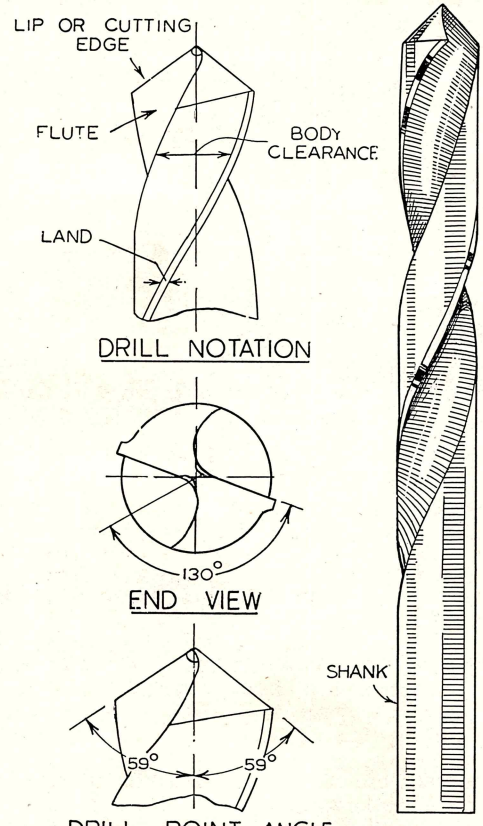
453. What is the Taper of a Parallel Reamer?

Certain types of parallel reamers have a taper of ·007 in. to ·010 in. from the end to commencement of the parallel portion.

454. How should a Quantity of Taper Pins be Ordered?

Give the name of the material, the length, and the size of the small end of the taper pin.

MORSE TWIST DRILLS



455. To what Angles should a Morse Twist Drill be Ground?

The angles are governed by the material to be drilled. Usually the cutting angle is 59° and the clearance angle 12°.

456. What Marks must the Aircraft have Painted or Affixed to It?

Nationality and registration marks.

The nationality mark for Great Britain is the capital letter "G."

The registration marks consist of four capital letters . . . G—ABCD.

To the fuselage must also be affixed a metal plate with the name and address of the owner, and also the marks of nationality and registration.

457. Why is the Sulphur Content in Steel Kept as Low as Possible?

If the percentage of sulphur is high then the steel will be "Red Short," i.e. it will have a tendency to crack if worked above a dull red heat.

458. How can Duralumin Rivets be Tested for Corrosion?

When inspecting a riveted structure, rub the rivets with a piece of hard wood. If the rivets are corroded the heads will collapse and form a white powder.

459. What Type of Seam is Used to Join Fabric?

The double balloon seam.

460. When must a Lifebelt be Carried for Each Person on board an Aircraft?

For flights with a radius of more than ten miles from the nearest land.

461. Describe the Action for Setting a Turnbuckle when Renewing a Control Cable.

Screw the fork ends into the barrel until half the plain is showing.

462. How is it Possible to Ascertain whether the Internal Bracing Wires Inside a Covered Main Plane are Broken or Slack?

The fabric will be wrinkled and distorted. If a rib is lightly tapped the broken wire will drum inside the plane.

463. How should Soggy Fabric be Treated?

Remove the dope and varnish with dope solvent. Inspect the fabric, and if serviceable apply the necessary new coats of dope and varnish.

464. Why is the Phosphorous Content in Steel Kept as Low as Possible?

If the percentage of phosphorous is high then the steel will be " Cold Short," i.e. it will have a tendency to crack if worked below a dull red heat.

465. How Many Strands and Wires are there in an Aircraft Cable?

15 cwt. to 100 cwt. cable has seven strands, each strand consisting of 19 wires.

466. When Hardening, why Quench Steel in Oil?

There is less possibility of the steel cracking when quenched in oil. Oil quenching is not so drastic as water quenching, with the result the maximum hardness of plain carbon steel will not be obtained, but the toughness will be greater.

467. Under what Conditions must the Aircraft have a Turn Indicator Fitted?

If the aircraft is capable of carrying five or more persons, including the crew, then a turn indicator must be fitted.

468. What Anti-corrosive Treatment is Applied to Cable by the Maker?

Flexible and extra-flexible cable is galvanized. Straining or Bowden cable is galvanized and tinned.

469. What Precautions are Taken when Bending Copper Tubes?

They should be in the fully softened condition. Anneal at 650° C., quench, in water, and fill tube with resin for acute bends to obviate kinks. When no resin is available use fine sand and plug the ends.

470. Is a Pilot who is a G.E. Permitted to Sign Out His Own Aircraft?

Yes, if in possession of G.E. Licences A and C.

471. Why are Brass Locknuts Used?

The thread of the locknut will strip before the thread of the wire.

472. What Instruments must be Fitted in an Aircraft to Obtain a Certificate of Airworthiness?

Air-speed indicator. Altimeter. Revolution indicator. Gauges as considered necessary.

473. When must the Aircraft have a Compass Fitted?

When the flight exceeds 20 miles from the point of departure.

474. How may a Spirit Level be Tested for Accuracy?

Place the level on a flat surface, and mark the position of the ends of the level. Also note the position of the bubble, reverse the level, and place it between the marks. If the level is accurate the bubble will take up the same position as before.

475. What Persons can Certify an Overhaul or Repair?

Those in possession of G.E. Licence "B" category (aircraft).

Those in possession of G.E. Licence "D" category (engines).

476. How should a Faulty Rivet be Removed?

File a flat on the maker's head, centre pop the centre of the flat, drill the depth of the rivet head with a drill the same size or smaller than the diameter of the rivet, shear the drilled head off with a cold chisel, and punch out the rivet shank, using a rivet the same size as the rivet being removed, taking care not to distort the hole.

477. What is the Weight of a Gallon of Oil?

9 lb. approx.

478. How may a Straightedge be Tested for Accuracy?

It can be checked by sighting along the edges. For absolute accuracy check on a surface table, using a dial gauge.

479. How many Hand Fire Extinguishers must be Carried if the Aircraft can carry Ten or More Persons?

A minimum of two extinguishers.

480. How many Times should a Split Pin be Used?

Split pins must only be used once.

481. What is the Guard for on Pulleys?

It prevents the cable running off the pulley.

482. What is the Tare Weight of an Aircraft?

The weight of the aircraft empty, without crew, oil or petrol, etc., but if radiators are fitted they should be filled with water before weighing.

483. What is the Weight of a Gallon of Water?

10 lb. approx.

484. How may a Fitter's Square be Tested for Accuracy?

Place the stock against the true edge of the material and scribe a line to the outside of the blade. Then turn the square over and scribe a second line. These two

lines should be parallel. Repeat on the inside of the blade. The stock should then be checked for parallelism. A fitter's square can also be checked with a " Master " square.

485. The Pilot Reports that the Controls are Stiff. Give possible Causes of This.

The control wires may be too tight, or there may be lack of lubrication of the moving parts. Stiff aileron controls may result from incorrect droop. The cables may be frayed at the fairleads, or incorrect bolts may be fitted in the control system.

486. How should the Aircraft be Supported to Obtain Rigging Position?

Supporting is governed by the type of aircraft. Usually the wheels are chocked front and rear, then the tail is raised and placed on a trestle under the rear jacking points, a weight is placed on the ground under the tail of the aircraft and a rope from the weight is attached to the tail, then place a trestle under the front jacking points, adjusting the trestles until aircraft is in rigging position.

487. What Lubricants are Used when Drilling?

Mild steel—mineral oil. Aluminium—paraffin. Cast iron or brass—nil.

488. What is the Strength of 25 cwt. Cable?

Slightly above 25 cwt.

489. When must a Machine be Signed Out Twice in 24 Hours?

When the machine lands owing to a defect which cannot be remedied by the pilot or crew.

490. Why should the Holes be Drilled Oversize for Solid Rivets?

The clearance depends on the material of the rivets. The object is to allow for expansion during riveting. In the case of thin gauge material the plates would tend to buckle and distort during the operation of riveting if no allowance had been made previously.

491. How is End Float Reduced on the Undercarriage Wheels?

By fitting shims.

492. How do the Manufacturers Guard Against Claims of Inaccuracy regarding their Special Rigging Levels?

The screws securing the level to the board are generally sealed with a blob of solder and stamped by their inspector.

493. How may a Duralumin Bolt be Recognized?

By weight and colour (generally anodically treated). It has also a collar under the head.

494. What Effect will Too Little Incidence have upon a Machine?

It will impart a tendency to fly nose-heavy.

495. To Stitch the Fabric along the Leading Edge What Stitch should be Used?

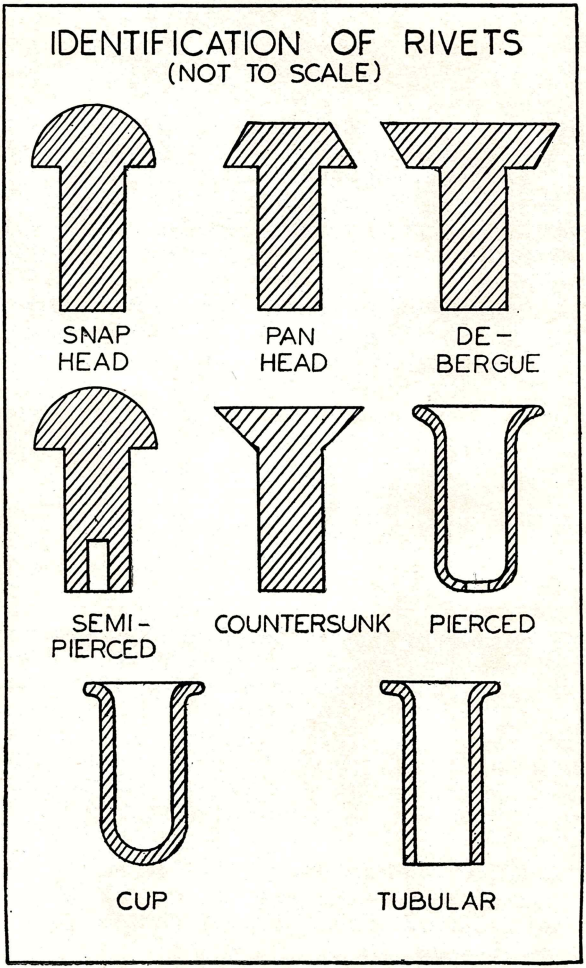
The ladder stitch.

496. Assuming that the Tyres and Oleo Legs are Satisfactory, what Defect in the Undercarriage would Cause a Machine to Taxi with One Wing Down?

The undercarriage may not be symmetrical about the centre line of the machine. Incorrect assembly of the undercarriage or incorrect or slack adjustment of the cross-bracing wires will cause this defect.

497. What is Meant by a Plus Thread?

That the thread exceeds the diameter of the bolt. Minus thread is when the thread is of the same diameter or less than the bolt.


IDENTIFICATION OF RIVETS
(NOT TO SCALE)
SNAP HEAD
PAN HEAD
DE-BERGUE
SEMI-PIERCED
COUNTERSUNK
PIERCED
CUP
TUBULAR

498. How much Rivet should be Allowed Above the Plate to Form a Snap Head Rivet (Duralumin)?

1·75 times the diameter of the rivet, though the thickness of the plates must be considered.

499. What Steps should be Taken to Deal with Corrosion that had already taken place on a Mild Steel Fitting?

If pitted, the fitting must be renewed. If surface corrosion has taken place, clean off with paraffin and wipe dry with a rag, then apply an anti-corrosive treatment (air-drying enamel).

500. What Documents must be Carried when Flying for Hire?

Certificate of Airworthiness.
Journey Log Book.
Certificate of Registration.
Certificates of the crew.
Passengers' names or particulars of freight.

501. A Pilot Reports that the Aircraft is Flying Nose-heavy. What will Cause this Defect?

The stagger may be incorrect, the incidence of the main planes may be the same but incorrect, the engine bearers may be out of alignment, the incidence of the tail plane may be incorrect, or the loading incorrect.

502. Why is a Small Percentage of Phosphorus Allowed in Steel Used to Make Bolts?

Phosphorus is added to obtain a free cutting steel, which is an advantage when cutting the thread. The disadvantage, if the phosphorus content is high, is the relative brittleness and low Izod value of the steel.

503. When Riveting Duralumin, are Rivets Used other than Duralumin?

Duralumin, hiduminium or aluminium rivets can be used.

504. What is Meant by the Gross Weight of the Aircraft?

The maximum flying weight of the aircraft as authorized, and shown on the Certificate of Airworthiness.

505. Explain the Term "Dihedral Angle."

The dihedral angle is formed by the upward and outward inclination of the main planes to the horizontal, measured when the aircraft is in rigging position.

506. How can Centigrade be Converted to Fahrenheit and Vice Versa?

Centigrade = F $-$ 32 $\div$ 9 $\times$ 5.
Fahrenheit = C. $\div$ 5 $\times$ 9 $+$ 32.

REFERENCE SECTION

LOGARITHMS

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Hyperbolic Logarithms = Common Logarithms × 2·30258.

LOGARITHMS

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96	9823	9827	9832	9836	9841	9845	9850	9854	9859	9863	0	1	1	2	2	3	3	4	4
97	9868	9872	9877	9881	9886	9890	9894	9899	9903	9908	0	1	1	2	2	3	3	4	4
98	9912	9917	9921	9926	9930	9934	9939	9943	9948	9952	0	1	1	2	2	3	3	4	4
99	9956	9961	9965	9969	9974	9978	9983	9987	9991	9996	0	1	1	2	2	3	3	3	4

Common Logarithms = Hyperbolic Logarithms × 0·43429

ANTILOGARITHMS

	0	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9
·00	1000	1002	1005	1007	1009	1012	1014	1016	1019	1021	0	0	1	1	1	1	2	2	2
·01	1023	1026	1028	1030	1033	1035	1038	1040	1042	1045	0	0	1	1	1	1	2	2	2
·02	1047	1050	1052	1054	1057	1059	1062	1064	1067	1069	0	0	1	1	1	1	2	2	2
·03	1072	1074	1076	1079	1081	1084	1086	1089	1091	1094	0	0	1	1	1	1	2	2	2
·04	1095	1099	1102	1104	1107	1109	1112	1114	1117	1119	0	1	1	1	1	2	2	2	2
·05	1122	1125	1127	1130	1132	1135	1138	1140	1143	1146	0	1	1	1	1	2	2	2	2
·06	1148	1151	1153	1156	1159	1161	1164	1167	1169	1172	0	1	1	1	1	2	2	2	2
·07	1175	1178	1180	1183	1186	1189	1191	1194	1197	1199	0	1	1	1	1	2	2	2	2
·08	1202	1205	1208	1211	1213	1216	1219	1222	1225	1227	0	1	1	1	1	2	2	2	3
·09	1230	1233	1236	1239	1242	1245	1247	1250	1253	1256	0	1	1	1	1	2	2	2	3
·10	1259	1262	1265	1268	1271	1274	1276	1279	1282	1285	0	1	1	1	1	2	2	2	3
·11	1288	1291	1294	1297	1300	1303	1306	1309	1312	1315	0	1	1	1	2	2	2	2	3
·12	1318	1321	1324	1327	1330	1334	1337	1340	1343	1346	0	1	1	1	2	2	2	2	3
·13	1349	1352	1355	1358	1361	1365	1368	1371	1374	1377	0	1	1	1	2	2	2	3	3
·14	1380	1384	1387	1390	1393	1396	1400	1403	1406	1409	0	1	1	1	2	2	2	3	3
·15	1413	1416	1419	1422	1426	1429	1432	1435	1439	1442	0	1	1	1	2	2	2	3	3
·16	1445	1449	1452	1455	1459	1462	1466	1469	1472	1476	0	1	1	1	2	2	2	3	3
·17	1479	1483	1486	1489	1493	1496	1500	1503	1507	1510	0	1	1	1	2	2	2	3	3
·18	1514	1517	1521	1524	1528	1531	1535	1538	1542	1545	0	1	1	1	2	2	2	3	3
·19	1549	1552	1556	1560	1563	1567	1570	1574	1578	1581	0	1	1	1	2	2	3	3	3
·20	1585	1589	1592	1596	1600	1603	1607	1611	1614	1618	0	1	1	1	2	2	3	3	3
·21	1622	1626	1629	1633	1637	1641	1644	1648	1652	1656	0	1	1	2	2	2	3	3	3
·22	1660	1663	1667	1671	1675	1679	1683	1687	1690	1694	0	1	1	2	2	2	3	3	3
·23	1698	1702	1706	1710	1714	1718	1722	1726	1730	1734	0	1	1	2	2	2	3	3	4
·24	1738	1742	1746	1750	1754	1758	1762	1766	1770	1774	0	1	1	2	2	2	3	3	4
·25	1778	1782	1786	1791	1795	1799	1803	1807	1811	1816	0	1	1	2	2	2	3	3	4
·26	1820	1824	1828	1832	1837	1841	1845	1849	1854	1858	0	1	1	2	2	3	3	3	4
·27	1862	1866	1871	1875	1879	1884	1888	1892	1897	1901	0	1	1	2	2	3	3	3	4
·28	1905	1910	1914	1919	1923	1928	1932	1936	1941	1945	0	1	1	2	2	3	3	4	4
·29	1950	1954	1959	1963	1968	1972	1977	1982	1986	1991	0	1	1	2	2	3	3	4	4
·30	1995	2000	2004	2009	2014	2018	2023	2028	2032	2037	0	1	1	2	2	3	3	4	4
·31	2042	2046	2051	2056	2061	2065	2070	2075	2080	2084	0	1	1	2	2	3	3	4	4
·32	2089	2094	2099	2104	2109	2113	2118	2123	2128	2133	0	1	1	2	2	3	3	4	4
·33	2138	2143	2148	2153	2158	2163	2168	2173	2178	2183	0	1	1	2	2	3	3	4	4
·34	2188	2193	2198	2203	2208	2213	2218	2223	2228	2234	1	1	2	2	3	3	4	4	5
·35	2239	2244	2249	2254	2259	2265	2270	2275	2280	2286	1	1	2	2	3	3	4	4	5
·36	2291	2296	2301	2307	2312	2317	2323	2328	2333	2339	1	1	2	2	3	3	4	4	5
·37	2344	2350	2355	2360	2366	2371	2377	2382	2388	2393	1	1	2	2	3	3	4	4	5
·38	2399	2404	2410	2415	2421	2427	2432	2438	2443	2449	1	1	2	2	3	3	4	4	5
·39	2455	2460	2466	2472	2477	2483	2489	2495	2500	2506	1	1	2	2	3	3	4	5	5
·40	2512	2518	2523	2529	2535	2541	2547	2553	2559	2564	1	1	2	2	3	4	4	5	5
·41	2570	2576	2582	2588	2594	2600	2606	2612	2618	2624	1	1	2	2	3	4	4	5	5
·42	2630	2636	2642	2649	2655	2661	2667	2673	2679	2685	1	1	2	2	3	4	4	5	6
·43	2692	2698	2704	2710	2716	2723	2729	2735	2742	2748	1	1	2	3	3	4	4	5	6
·44	2754	2761	2767	2773	2780	2786	2793	2799	2805	2812	1	1	2	3	3	4	4	5	6
·45	2818	2825	2831	2838	2844	2851	2858	2864	2871	2877	1	1	2	3	3	4	5	5	6
·46	2884	2891	2897	2904	2911	2917	2924	2931	2938	2944	1	1	2	3	3	4	5	5	6
·47	2951	2958	2965	2972	2979	2985	2992	2999	3006	3013	1	1	2	3	3	4	5	5	6
·48	3020	3027	3034	3041	3048	3055	3062	3069	3076	3083	1	1	2	3	4	4	5	6	6
·49	3090	3097	3105	3112	3119	3126	3133	3141	3148	3155	1	1	2	3	4	4	5	6	6

ANTILOGARITHMS

	0	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9
·50	3162	3170	3177	3184	3192	3199	3206	3214	3221	3228	1	1	2	3	4	4	5	6	7
·51	3236	3243	3251	3258	3266	3273	3281	3289	3296	3304	1	2	2	3	4	5	5	6	7
·52	3311	3319	3327	3334	3342	3350	3357	3365	3373	3381	1	2	2	3	4	5	5	6	7
·53	3388	3396	3404	3412	3420	3428	3436	3443	3451	3459	1	2	2	3	4	5	6	6	7
·54	3467	3475	3483	3491	3499	3508	3516	3524	3532	3540	1	2	2	3	4	5	6	6	7
·55	3548	3556	3565	3573	3581	3589	3597	3606	3614	3622	1	2	2	3	4	5	6	7	7
·56	3631	3639	3648	3656	3664	3673	3681	3690	3698	3707	1	2	3	3	4	5	6	7	8
·57	3715	3724	3733	3741	3750	3758	3767	3776	3784	3793	1	2	3	3	4	5	6	7	8
·58	3802	3811	3819	3828	3837	3846	3855	3864	3873	3882	1	2	3	4	4	5	6	7	8
·59	3890	3899	3908	3917	3926	3936	3945	3954	3963	3972	1	2	3	4	5	5	6	7	8
·60	3981	3990	3999	4009	4018	4027	4036	4046	4055	4064	1	2	3	4	5	6	6	7	8
·61	4074	4083	4093	4102	4111	4121	4130	4140	4150	4159	1	2	3	4	5	6	7	8	9
·62	4169	4178	4188	4198	4207	4217	4227	4236	4246	4256	1	2	3	4	5	6	7	8	9
·63	4266	4276	4285	4295	4305	4315	4325	4335	4345	4355	1	2	3	4	5	6	7	8	9
·64	4365	4375	4385	4395	4406	4416	4426	4436	4446	4457	1	2	3	4	5	6	7	8	9
·65	4467	4477	4487	4498	4508	4519	4529	4539	4550	4560	1	2	3	4	5	6	7	8	9
·66	4571	4581	4592	4603	4613	4624	4634	4645	4656	4667	1	2	3	4	5	6	7	9	10
·67	4677	4688	4699	4710	4721	4732	4742	4753	4764	4775	1	2	3	4	5	7	8	9	10
·68	4786	4797	4808	4819	4831	4842	4853	4864	4875	4887	1	2	3	4	6	7	8	9	10
·69	4898	4909	4920	4932	4943	4955	4966	4977	4989	5000	1	2	3	5	6	7	8	9	10
·70	5012	5023	5035	5047	5058	5070	5082	5093	5105	5117	1	2	4	5	6	7	8	9	11
·71	5129	5140	5152	5164	5176	5188	5200	5212	5224	5236	1	2	4	5	6	7	8	10	11
·72	5248	5260	5272	5284	5297	5309	5321	5333	5346	5358	1	2	4	5	6	7	9	10	11
·73	5370	5383	5395	5408	5420	5433	5445	5458	5470	5483	1	3	4	5	6	8	9	10	11
·74	5495	5508	5521	5534	5546	5559	5572	5585	5598	5610	1	3	4	5	6	8	9	10	12
·75	5623	5636	5649	5662	5675	5689	5702	5715	5728	5741	1	3	4	5	7	8	9	10	12
·76	5754	5768	5781	5794	5808	5821	5834	5848	5861	5875	1	3	4	5	7	8	9	11	12
·77	5888	5902	5916	5929	5943	5957	5970	5984	5998	6012	1	3	4	5	7	8	10	11	12
·78	6026	6039	6053	6067	6081	6095	6109	6124	6138	6152	1	3	4	6	7	8	10	11	13
·79	6166	6180	6194	6209	6223	6237	6252	6266	6281	6295	1	3	4	6	7	9	10	11	13
·80	6310	6324	6339	6353	6368	6383	6397	6412	6427	6442	1	3	4	6	7	9	10	12	13
·81	6457	6471	6486	6501	6516	6531	6546	6561	6577	6592	2	3	5	6	8	9	11	12	14
·82	6607	6622	6637	6653	6668	6683	6699	6714	6730	6745	2	3	5	6	8	9	11	12	14
·83	6761	6776	6792	6808	6823	6839	6855	6871	6887	6902	2	3	5	6	8	9	11	13	14
·84	6918	6934	6950	6966	6982	6998	7015	7031	7047	7063	2	3	5	6	8	10	11	13	15
·85	7079	7096	7112	7129	7145	7161	7178	7194	7211	7228	2	3	5	7	8	10	12	13	15
·86	7244	7261	7278	7295	7311	7328	7345	7362	7379	7396	2	3	5	7	8	10	12	13	15
·87	7413	7430	7447	7464	7482	7499	7516	7534	7551	7568	2	4	5	7	9	10	12	14	16
·88	7586	7603	7621	7638	7656	7674	7691	7709	7727	7745	2	4	5	7	9	11	12	14	16
·89	7762	7780	7798	7816	7834	7852	7870	7889	7907	7925	2	4	5	7	9	11	13	14	16
·90	7943	7962	7980	7998	8017	8035	8054	8072	8091	8110	2	4	6	7	9	11	13	15	17
·91	8128	8147	8166	8185	8204	8222	8241	8260	8279	8299	2	4	6	8	9	11	13	15	17
·92	8318	8337	8356	8375	8395	8414	8433	8453	8472	8492	2	4	6	8	10	12	14	15	17
·93	8511	8531	8551	8570	8590	8610	8630	8650	8670	8690	2	4	6	8	10	12	14	16	18
·94	8710	8730	8750	8770	8790	8810	8831	8851	8872	8892	2	4	6	8	10	12	14	16	18
·95	8913	8933	8954	8974	8995	9016	9034	9057	9078	9099	2	4	6	8	10	12	15	17	19
·96	9120	9141	9162	9183	9204	9226	9247	9268	9290	9311	2	4	6	8	11	13	15	17	19
·97	9333	9354	9376	9397	9419	9441	9462	9484	9506	9528	2	4	7	9	11	13	15	17	20
·98	9550	9572	9594	9616	9638	9661	9683	9705	9727	9750	2	4	7	9	11	13	16	18	20
·99	9772	9795	9817	9840	9863	9886	9908	9931	9954	9977	2	5	7	9	11	14	16	18	20

COMMON FRACTIONS OF AN INCH IN DECIMALS AND MILLIMETRES*

Common Fractions	Decimal Fractions	Millimetres	Common Fractions	Decimal Fractions	Millimetres
1/64	·0156	0·40	33/64	·5156	13·10
1/32	·0313	0·79	17/32	·5313	13·49
3/64	·0469	1·19	35/64	·5469	13·89
1/16	·0625	1·59	9/16	·5625	14·29
5/64	·0781	1·99	37/64	·5781	14·69
3/32	·0933	2·33	19/32	·5938	15·08
7/64	·1094	2·78	39/64	·6094	15·48
1/8	·1250	3·18	5/8	·6250	15·88
9/64	·1406	3·57	41/64	·6406	16·27
5/32	·1563	3·97	21/32	·6563	16·67
11/64	·1719	4·37	43/64	·6719	17·07
3/16	·1875	4·77	11/16	·6875	17·47
13/64	·2031	5·16	45/64	·7031	17·86
7/32	·2188	5·56	23/32	·7188	18·26
15/64	·2344	5·96	47/64	·7344	18·66
1/4	·2500	6·35	3/4	·7500	19·05
17/64	·2656	6·75	49/64	·7656	19·45
9/32	·2813	7·15	25/32	·7813	19·85
19/64	·2969	7·54	51/64	·7969	20·24
5/16	·3125	7·94	13/16	·8125	20·64
21/64	·3281	8·34	53/64	·8281	21·04
11/32	·3438	8·73	27/32	·8438	21·43
23/64	·3594	9·13	55/64	·8594	21·83
3/8	·3750	9·53	7/8	·8750	22·23
25/64	·3906	9·92	57/64	·8906	22·62
13/32	·4063	10·32	29/32	·9063	23·02
27/64	·4219	10·72	59/64	·9219	23·62
7/16	·4375	11·12	15/16	·9375	23·81
29/64	·4531	11·51	61/64	·9531	24·21
15/32	·4688	11·91	31/32	·9688	24·61
31/64	·4844	12·31	63/64	·9844	25·00
1/2	·5000	12·70	1″	1·0000	25·40

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Areas of Circles in Square Inches

Diameters in Inches and $\frac{1}{8}$ths

Diameter in Inches.	0 in.	$\frac{1}{8}$ in.	$\frac{1}{4}$ in.	$\frac{3}{8}$ in.	$\frac{1}{2}$ in.	$\frac{5}{8}$ in.	$\frac{3}{4}$ in.	$\frac{7}{8}$ in.
0	0·0	0·0122	0·0490	0·1104	0·1963	0·3068	0·4417	0·6013
1	0·7854	0·9940	1·227	1·484	1·767	2·073	2·405	2·761
2	3·141	3·546	3·976	4·430	4·908	5·441	5·939	6·491
3	7·068	7·669	8·295	8·946	9·621	10·32	11·04	11·79
4	12·56	13·36	14·18	15·03	15·90	16·80	17·72	18·66
5	19·63	20·62	21·64	22·69	23·75	24·85	25·96	27·10
6	28·27	29·46	30·67	31·91	33·18	34·47	35·78	37·12
7	38·48	39·87	41·28	42·71	44·17	45·66	47·17	48·70
8	50·26	51·84	53·45	55·08	56·74	58·42	60·13	61·86
9	63·61	65·39	67·20	69·02	70·88	72·75	74·66	76·58
10	78·54	80·51	82·51	84·54	86·59	88·66	90·76	93·88
11	95·03	97·20	99·40	101·6	103·8	106·1	108·4	110·7
12	113·0	115·4	117·8	120·2	122·7	125·1	127·6	130·1
13	132·7	135·2	137·8	140·5	143·1	145·8	148·4	151·2
14	153·9	156·6	159·4	162·2	165·1	167·9	170·8	173·7
15	176·7	179·6	182·6	185·6	188·6	191·7	194·8	197·9
16	201·0	204·2	207·3	210·5	213·1	217·0	220·3	223·6
17	226·9	230·3	233·7	237·1	240·5	243·9	247·4	250·9
18	254·4	258·0	261·5	265·1	268·8	272·4	276·1	279·8
19	283·5	287·2	291·0	294·8	298·6	302·4	306·3	310·2
20	314·1	318·1	322·0	326·0	330·0	334·1	338·1	342·2
21	346·3	350·4	354·6	358·8	363·0	367·2	371·5	375·8

USEFUL FORMULÆ *

Circumference of a circle	= diameter × 3·1416.
	= radius × 6·2832.
Radius of a circle	= circumference × ·159155
Diameter of a circle	= circumference × ·31831
Side of an inscribed equilateral triangle	= diameter of circle × ·86
Side of an inscribed cube	= radius of sphere × 1·1547
Side of an inscribed square	= diameter of circle × ·7071
	= circumference of circle × ·225.
Area of a circle	= radius ^{2} × 3·1416
	= diameter^2 = ·7854
	= circumference ^{2} × ·07958
Area of a square	= a side ^{2}
Area of a triangle	= base × ½ altitude.
Area of a rectangle	= base × altitude.
Area of a parallelogram	= base × altitude.
Area of a trapezoid	= altitude × ½ sum of parallel sides.
Area of a parabola	= ⅔ base × altitude of exterior triangle.
Area of a trapezium	= area of the two constituent triangles.
Area of a regular polygon	= ½ the perpendicular from the centre to one of the sides × sum of the sides.
Area of a sector	= ½ radius × arc.
Area of an ellipse	= ½ short diameter × ½ long diameter × 3·1416.

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USEFUL FORMULÆ (Continued)

Surface of a sphere	= circumference × diameter
	= diameter ^{2} × 3·1416
Surface of a cube	= area of one side × 6
Surface of a cylinder	= area of both ends + (length × circumference).
Surface of a zone or convex surface of segment of a sphere	= 6·2832 × radius of sphere from which it is cut × altitude of the zone.
Surface of a frustum of a cone	= ½ (sum of circumferences at both ends) × slant height + area of both ends.
Volume of a sphere	= surface × ⅙ diameter.
	= diameter ^{3} × ·5236
Volume of a cube	= one side^3.
Volume of a cylinder or prism	= area of end × length.
Volume of a cone or pyramid	= area of base × ⅓ altitude.
Volume of a frustum of a cone or pyramid	= ⅓ altitude (area of both ends + square root of areas of both ends multiplied together).
Volume of a wedge	= area of base × ½ altitude.
Volume of a spherical segment of one base	= ½ altitude × 3·1416 × radius of base ^{2} + ⅙ altitude ^{3} × 3·1416

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1 pound avoirdupois	= 7000 grains.
Weight of 1 cubic foot of fresh water	= 62·28 pounds at 62 deg. F.

A column of water 2·31 feet high corresponds to a pressure of 1 pound per square inch.

EQUIVALENT TEMPERATURES IN CENTIGRADE AND FAHRENHEIT

Cent.°	Fahr.°	Cent.°	Fahr.°	Cent.°	Fahr.°	Cent.°	Fahr.°
180	356	360	680	545	1013	725	1337
185	365	365	689	550	1022	730	1346
190	374	370	698	555	1031	735	1355
195	383	375	707	560	1040	740	1364
200	392	380	716	565	1049	745	1373
205	401	385	725	570	1058	750	1382
210	410	390	734	575	1067	755	1391
215	419	395	743	580	1076	760	1400
220	428	400	752	585	1085	765	1409
225	437	405	761	590	1094	770	1418
230	446	410	770	595	1103	775	1427
235	455	415	779	600	1112	780	1436
240	464	420	788	605	1121	785	1445
245	473	425	797	610	1130	790	1454
250	482	430	806	615	1139	795	1463
255	491	435	815	620	1148	800	1472
260	500	440	824	625	1157	805	1481
265	509	445	833	630	1166	810	1490
270	518	450	842	635	1175	815	1499
275	527	455	851	640	1184	820	1508
280	536	460	860	645	1193	825	1517
285	545	465	869	650	1202	830	1526
290	554	470	878	655	1211	835	1535
295	563	475	887	660	1220	840	1544
300	572	480	896	665	1229	845	1553
305	581	485	905	670	1238	850	1562
310	590	490	914	675	1247	855	1571
315	599	495	923	680	1256	860	1580
320	608	500	932	685	1265	865	1589
325	617	505	941	690	1274	870	1598
330	626	510	950	695	1283	875	1607
335	635	515	959	700	1292	880	1616
340	644	520	968	705	1301	885	1625
345	653	525	977	710	1310	890	1634
350	662	530	986	715	1319	895	1643
355	671	535	995	720	1328	900	1652
		540	1004				

British Standard Fine Threads

Diameter	Threads per in.	Pitch, in.	Depth of Thread	Core Diam., in.	Diam. of Tap Drill, in.
$\frac{1}{4}$	26	·0385	·0246	0·2007	No. 7
$\frac{5}{16}$	22	·0455	·0291	0·2543	G
$\frac{3}{8}$	20	·0500	·0320	0·3110	O
$\frac{7}{16}$	18	·0556	·0356	0·3664	U
$\frac{1}{2}$	16	·0625	·0400	0·4200	$\frac{27}{64}$
$\frac{9}{16}$	16	·0625	·0400	0·4825	$\frac{31}{64}$
$\frac{5}{8}$	14	·0714	·0457	0·5335	$\frac{35}{64}$
$\frac{11}{16}$	14	·0714	·0457	0·5960	$\frac{19}{32}$
$\frac{3}{4}$	12	·0833	·0534	0·6433	$\frac{21}{32}$
$\frac{13}{16}$	12	·0833	·0534	0·7058	18 mm.
$\frac{7}{8}$	11	·0909	·0582	0·7586	$\frac{49}{64}$
$\frac{15}{16}$	11	·0909	·0582	0·8211	21 mm.
1	10	·1000	·0640	0·8719	$\frac{7}{8}$
$1\frac{1}{8}$	9	·1111	·0711	0·9827	$\frac{63}{64}$
$1\frac{1}{4}$	9	·1111	·0711	1·1077	$1\frac{7}{64}$
$1\frac{3}{8}$	8	·1250	·0800	1·2149	$1\frac{7}{32}$
$1\frac{1}{2}$	8	·1250	·0800	1·3399	$1\frac{11}{32}$
$1\frac{5}{8}$	8	·1250	·0800	1·4649	$1\frac{15}{32}$
$1\frac{3}{4}$	7	·1429	·0915	1·5670	40 mm.
$1\frac{7}{8}$	7	·1429	·0915	1·6920	$1\frac{45}{64}$
2	7	·1429	·0915	1·8170	$1\frac{53}{64}$
$2\frac{1}{8}$	7	·1429	·0915	1·9420	$1\frac{61}{64}$
$2\frac{1}{4}$	6	·1667	·1067	2·0366	52 mm.
$2\frac{3}{8}$	6	·1667	·1067	2·1616	55 mm.
$2\frac{1}{2}$	6	·1667	·1067	2·2866	$2\frac{5}{16}$

With acknowledgements to Practical Mechanics Handbook.

Wire and Sheet-metal Gauges

Number of Gauge	British Imperial Standard or English Legal Standard		Number of Gauge	British Imperial Standard or English Legal Standard	
	in.	mm.		in.	mm.
7/0	·500	12·70	16	·064	1·625
6/0	·464	11·78	17	·056	1·422
5/0	·432	10·97	18	·048	1·219
4/0	·400	10·16	19	·040	1·016
3/0	·372	9·44	20	·036	0·914
2/0	·348	8·83	21	·032	0·812
1/0	·324	8·23	22	·028	0·711
1	·300	7·62	23	·024	0·61
2	·276	7·06	24	·022	0·558
3	·252	6·40	25	·020	0·508
4	·232	5·89	26	·018	0·457
5	·212	5·38	27	·016	0·406
6	·192	4·88	28	·0148	0·376
7	·176	4·46	29	·0136	0·345
8	·160	4·06	30	·012	0·304
9	·144	3·66	31	·0116	0·29
10	·128	3·24	32	·0108	0·274
11	·116	2·94	33	·010	0·254
12	·104	2·642	34	·009	0·228
13	·092	2·336	35	·008	0·203
14	·080	2·03	36	·0076	0·193
15	·072	1·828			

With acknowledgements to Practical Mechanics Handbook.

British Association Screws

No.	Absolute Dimensions in Millimetres.		Approximate Number of Threads per Inch.	Approximate Dimensions in Inches.	
	Full Diameter.	Pitch.		Full Diameter.	Pitch.
25	0·25	0·07	362·8	·010	·0028
24	0·29	0·08	317·5	·011	·0031
23	0·33	0·09	282·2	·013	·0035
22	0·37	0·10	254·0	·015	·0039
21	0·42	0·11	230·9	·017	·0043
20	0·48	0·12	211·6	·019	·0047
19	0·54	0·14	181·4	·021	·0055
18	0·62	0·15	169·3	·024	·0059
17	0·70	0·17	149·4	·028	·0067
16	0·79	0·19	133·7	·031	·0075
15	0·90	0·21	121·0	·035	·0083
14	1·0	0·23	110·4	·039	·0091
13	1·2	0·25	101·6	·047	·0098
12	1·3	0·28	90·7	·051	·0110
11	1·5	0·31	81·9	·059	·0122
10	1·7	0·35	72·6	·067	·0138
9	1·9	0·39	65·1	·075	·0154
8	2·2	0·43	59·1	·087	·0169
7	2·5	0·48	52·9	·098	·0189
6	2·8	0·53	47·9	·110	·0209
5	3·2	0·59	43·0	·126	·0232
4	3·6	0·66	38·5	·142	·0260
3	4·1	0·73	34·8	·161	·0287
2	4·7	0·81	31·4	·185	·0319
1	5·3	0·90	28·2	·209	·0354
0	6·0	1·00	25·4	·236	·0394

With acknowledgements to Practical Mechanics Handbook.

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Printed in Great Britain by Butler & Tanner Ltd., Frome and London